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BIOLOGICAL EFFECTS OF ELECTROMAGNETIC RADIATION


A Digest of Current Literature and a
Forum of Communication

A QUARTERLY PUBLICATION
PRODUCED FOR
U.S. ARMY RESEARCH OFFICE

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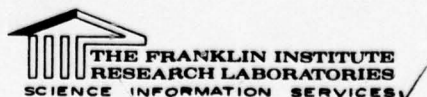
Biological Effects of Electromagnetic Radiation serves as a vehicle through which current documentation of research highlights on the biological effects and health implications of nonionizing electromagnetic radiation (microwave and radiofrequency radiation) are compiled, condensed and disseminated on a regular basis. BEEMR is intended to be a highly useful current awareness tool for scientists engaged in research or related activities. The great number and diversity of relevant publications make imperative the availability of this service to persons whose work requires that they keep abreast of current developments in the field.

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BIOLOGICAL EFFECTS OF ELECTROMAGNETIC RADIATION

A Digest of Current Literature and a
Forum of Communication

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VOLUME I

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by

THE FRANKLIN INSTITUTE RESEARCH LABORATORIES

Science Information Services

Biomedical Section

Bruce H. Kleinstein, Ph.D., Technical Editor

PREFACE

Due to printing delays, Volume I, issue 1 and Volume I, issue 2 of *Biological Effects of Electromagnetic Radiation* have been condensed and combined into one joint issue. Normally, the digest is published quarterly and will include materials received during the preceding three months. Each issue will include news items and announcements, a listing of meetings and conferences, abstracts of current literature, and a directory of current research. Materials for which full text is not available will be included as citations. When available, a special report section, technical note, book review, or topical retrospective literature survey will be included.

Biological Effects of Electromagnetic Radiation is a publication researched and prepared by the Franklin Institute Research Laboratories, Science Information Services Department, under a grant from the U.S. Army Research Office. The grant is co-sponsored by the Bureau of Radiological Health, Food and Drug Administration; Office of Naval Research; U.S. Navy Bureau of Medicine and Surgery; U.S. Air Force School of Aerospace Medicine; and the Walter Reed Army Institute of Research. The U.S. Environmental Protection Agency is cooperating in this project.

Biological Effects of Electromagnetic Radiation serves as a vehicle through which current documentation of research highlights on the biological effects and health implications of nonionizing electromagnetic radiation (microwave and radiofrequency radiation) are compiled, condensed and disseminated on a regular basis. *Biological Effects of Electromagnetic Radiation* is intended to be a highly useful current awareness tool for scientists engaged in research or related activities. The great number and diversity of relevant publications make imperative the availability of this service to persons whose work requires that they keep abreast of current developments in the field.

MEETINGS and CONFERENCES

**** SEVENTH ANNUAL WINTER CONFERENCE ON BRAIN RESEARCH.

Date: January 19-26, 1974
Place: Steamboat Springs, Colorado
Sponsor: Barrow Neurological Institute
Requests for Information: Barrow Neurological Inst., Michigan State University, East Lansing, Michigan 48823.

Selected Bibliography of Papers Presented:

THRESHOLD EFFECTS OF MICROWAVE RADIATION ON EMBRYO CELL SYSTEMS. F. S. Barnes (Univ. Colorado, Boulder).

AN ANALYSIS OF A HEAT SENSOR VIA MICROWAVE STIMULATION. I. Gamow (Univ. Colorado, Boulder).

TWO VIEWS OF MICROWAVE EFFECTS ON THE CENTRAL NERVOUS SYSTEM: EAST AND WEST. E. Postow (Bur. Med. Surg., Navy, Washington, D. C.).

IMMEDIATE EFFECTS OF LOW INTENSITY MICROWAVES ON ISOLATED NEURONS. H. Wachtel (Duke Univ., Durham, N.C.).

**** SAN DIEGO BIOMEDICAL SYMPOSIUM 1974.

Date: February 6-8, 1974
Place: San Diego, California
Sponsor: American Society for Quality Control; Institute of Electrical and Electronics Engineers; Naval Hospital, San Diego; Naval Undersea Center; San Diego State University
Requests for Information: San Diego Biomedical Symposium, Box 965, San Diego, California 92112

Selected Bibliography of Papers Presented:

EFFECT ON FECUNDITY IN BIRDS EXPOSED TO VARIOUS ELECTROMAGNETIC FIELDS. A. J. Giarola (Texas A & M Univ., College Station, Texas).

**** CONFERENCE ON THE BIOLOGICAL EFFECTS OF NON-IONIZING RADIATION.

Date: February 12-15, 1974.
Place: Delmonico Hotel, New York City, New York
Sponsor: The New York Academy of Sciences
Request for Information: Paul E. Tyler, M. D., Conference Chairman, Head, EMR Project Office, Bur. Med. and Surg., Dept. of the Navy, Washington D. C.

Papers from this conference have been abstracted in Volume II, issue 2, of *Biological Effects of Electromagnetic Radiation*.

**** IEE-IMPI (EUROPE) MEETING ON THE MEASUREMENT OF ELECTROMAGNETIC RADIATION HAZARDS AND THEIR BIOLOGICAL EFFECTS.

Date: February 26, 1974
Place: Savoy Place, London, England
Sponsor: IEE/IEERE Medical and Biological Group; International Microwave Power Institute
Request for Information: IMPI, Box 1556, Edmonton, Alberta, Canada

Selected Bibliography of Papers Presented:

BIOLOGICAL EFFECTS OF MICROWAVES. C. R. Ricketts (M.R.C. Res. Unit, Birmingham Accident Hosp., U.K.).

THE ENGINEERING ASPECTS OF MICROWAVE RADIATION. R. B. Smith (Univ. Bradford, Yorkshire, England).

STANDARDS AND LEGISLATIVE ASPECTS OF MICROWAVE RADIATION HAZARDS. J. C. Gallagher (Univ. Bradford, Yorkshire, England).

SERVICES ASPECTS OF MICROWAVE HAZARDS. D. M. Field (R. R. E. Malvern, U. K.).

DIELECTRIC DISPERSION MEASUREMENTS ON BIOLOGICAL SOLUTIONS. E. H. Grant (Queen Elizabeth Coll., London, England).

METALLIC IMPLANTS AND MICROWAVE BLOOD WARNING. H. D. Baille (Ancoats and Crumpsall Hosp., Manchester, England).

THE EFFECTS OF MICROWAVES ON ISOLATED SKIN. J. C. Lawrence (M.R.C. Research Unit, Birmingham Accident Hosp., England).

**** 58TH ANNUAL MEETING OF THE FEDERATION OF AMERICAN SOCIETIES FOR EXPERIMENTAL BIOLOGY.

Date: April 7-12, 1974
Place: Atlantic City, New Jersey
Sponsor: Federation of American Societies for Experimental Biology
Requests for Information: Mrs. H. B. Lemp, FASEB, Atlantic City, New Jersey

Selected Bibliography of Papers Presented:

PHYSIOLOGIC ADJUSTMENTS TO MICROWAVE EXPOSURE. S. M. Michaelson (Univ. Rochester, Sch. Med. Dent., New York).

INCREASED BLOOD FLOW IN GLIAL TUMORS PRODUCED BY MICROWAVE HEATING. C. H. Sutton (Univ. Miami, Sch. Med., VA Hosp., Florida), R. L. Nunnally, F. B. Carroll and K. Kuban.

MEETINGS AND CONFERENCES

Biological Effects Electromagnetic Radiation 1(1), June 1974 and 1(2), September 1974

MICROWAVE RADIATION FOR THE ASSAY OF CYCLIC NUCLEOTIDES AND PUTATIVE NEUROTRANSMITTER CONCENTRATIONS IN BRAINS OF MICE AND RATS. C. T. Wang (Natl. Inst. Mental Hlth., Preclin. Pharm., St. Elizabeth's Hosp., Washington D. C.).

HEAT IN MALE CONTRACEPTION (HOT WATER 60°C, INFRA-RED, ULTRASOUND AND MICROWAVES). M. S. Fahim (Univ. Missouri Med. Ctr., Columbia), D. G. Hall and R. Der.

**** MICROWAVE POWER SYMPOSIUM AND MICROWAVE POWER FOR INDUSTRY. SHORT COURSE.

Date: May 28-31, 1974.

Place: Marquette University, Milwaukee, Wisconsin

Sponsor: International Microwave Power Institute; IEEE Milwaukee Section, Joint Milwaukee Chapter of the IEEE Microwave Theory and Techniques Society; IEEE Electron Devices Group.

Requests for Information: K. W. Hsu, Microwave Power Symposium 1974, Department of Electrical Engineering, Marquette University, Milwaukee, Wisconsin 53233.

Pertinent papers from this symposium have been abstracted in Volume I, issue 2, of *Biological Effects of Electromagnetic Radiation*.

**** SEVENTH ROCHESTER INTERNATIONAL CONFERENCE ON ENVIRONMENTAL TOXICITY: FUNDAMENTAL AND APPLIED ASPECTS OF NONIONIZING RADIATIONS.

Date: June 4-7, 1974.

Place: University of Rochester, School of Medicine and Dentistry, New York

Sponsor: Department of Radiation Biology and Biophysics, University of Rochester

Requests for Information: Mrs. Judy Havalock, Secretary to the Conference Chairman, Dept. Radiation Biology and Biophysics, School of Medicine and Dentistry, University of Rochester, 260 Crittenden Blvd., Rochester, New York 14642.

Selected Bibliography of Papers to be Presented:

PHYSIOLOGICAL RESPONSES TO HEAT. J. Bligh (Agri. Res. Council, Inst. Animal Physiology, Cambridge, England).

DOSIMETRY OF ELECTROMAGNETIC RADIATION. R. R. Bowman (Natl. Bur. Standards, Electromagnetic Div., Boulder, Colorado).

HEMATOLOGICAL EFFECTS. P. Czerski (Natl. Res. Inst. Mother Child, Dept. Human Genetics, Warsaw, Poland).

ANALYSIS OF OCCUPATIONAL EXPOSURE TO MICROWAVE RADIATION. P. Czerski (Natl. Res. Inst. Mother Child, Dept. Human Genetics, Warsaw, Poland).

HAZARDS OF OCCUPATIONAL EXPOSURE TO NONIONIZING RADIATION. Z. V. Gordon (Inst. Gigeny Truda i Professionalnych, Zabolevani AMN, Moscow, USSR).

ELECTROPHYSIOLOGICAL EFFECTS IN ANIMALS. A. W. Guy (Dept. Physical Med. Rehabil., Univ. Washington Sch. Med., Seattle).

ELECTROPHYSIOLOGICAL EFFECTS ON MAN. E. Klimkova-Deutschova (Univ. Clin., Neurology Dept., Prague, Czechoslovakia).

CONTROL OF OCCUPATIONAL EXPOSURE TO NONIONIZING RADIATION. T. Ely (Eastman Kodak Co., Lab. Industrial Med., Rochester, N.Y.).

PERCEPTION OF MICROWAVES. H. E. von Gierke (Biodynamics and Bionics Div. Aerospace Med. Res. Lab., Wright-Patterson AFB, Ohio) and Dr. Ing.

ELECTROMAGNETIC INCOMPATIBILITY OF MEDICAL PROSTHETIC DEVICES. J. Mitchell (USAF Sch. Aerospace Med., San Antonio, Texas).

PROSPECTS FOR EXPANSION OF INDUSTRIAL AND CONSUMER USES OF MICROWAVES. J. M. Osepchuk (Res. Div., Raytheon, Waltham, Mass.).

SAFETY OF MILITARY USE OF MICROWAVES. L. T. Odland (CMDR USAF Radiol. Hlth. Lab., Wright-Patterson AFB, Ohio).

DIELECTRIC PROPERTIES OF BIOLOGICAL MATERIALS. H. P. Schwan (Dept. Elec. Engineering, Univ. Pennsylvania, Moore Sch. Engineering, Philadelphia).

SELECTIVE HEATING, LOCALIZED HEATING AND SCALING THEORY. H. P. Schwan (Dept. Elec. Engineering, Univ. Pennsylvania, Moore Sch. Engineering, Philadelphia).

OVERVIEW OF STANDARDS FOR SAFETY FROM EXPOSURE TO NONIONIZING RADIATION. M. J. Suess (Reg. Off. Environ. Hlth., WHO, Reg. Hlth. Off. Europe, Copenhagen, Denmark).

**** IEEE S-MTT INTERNATIONAL MICROWAVE SYMPOSIUM.

Date: June 12-14, 1974.

Place: Georgia Inst. Technology, Atlanta, Georgia

Sponsor: Institute of Electrical and Electronics Engineering (S-MTT); Georgia Institute of Technology. *Requests for Information:* Registration Clerk, IEEE/S-MTT Symposium, Sch. Elec. Engineering, Georgia Inst. of Technology, Atlanta, Georgia 30332.

Selected Bibliography of Papers to be Presented:

A MICROWAVE DOSIMETRY SYSTEM FOR MEASURING SAMPLED INTEGRAL DOSE RATE. C. L. Christman (Div. Biological Effects, Bur. Radiol. Hlth., FDA, Rockville, Md.), H. S. Ho and S. Yarrow.

MICROWAVE EFFECT ON RABBIT SUPERIOR CERVICAL GANGLION. K. Courtney (Univ. Washington Sch. Med., Seattle), J. C. Lin, A. W. Guy and C. K. Chou.

A SURVEY OF THE POTENTIAL FOR BENEFICIAL APPLICATIONS OF MICROWAVES IN MEDICINE AND BIOLOGY. J. M. Osephchuk (Res. Div., Raytheon Co., Waltham, Mass.).

EXPERIMENTAL MODELS FOR THE EVALUATION OF MICROWAVE BIOLOGICAL EFFECTS. P. Czerski (Nat'l. Inst. Mother Child, Warsaw, Poland).

BEHAVIORAL CHANGES OF RATS EXPOSED TO MICROWAVE RADIATION. J. C. Lin (Univ. Washington Sch. Med., Seattle), A. W. Guy and L. R. Caldwell.

AN INTERNATIONAL PROGRAM FOR MICROWAVE EXPOSURE PROTECTION. S. M. Michaelson (Univ. Rochester, N.Y.) and M. J. Suess.

THERMOGENETIC AND CARDIODYNAMIC REGULATION IN DOGS CRANIALY EXPOSED TO 2450 MHZ (CW) MICROWAVES. Shin-Tsu-Lu (Univ. Rochester, N.Y.) and M. J. Suess.

ABSORPTION CHARACTERISTICS OF MULTI-LAYERED SPHERE MODELS EXPOSED TO UHF/MICROWAVE RADIATION. C. M. Weil (U.S. EPA, Res. Triangle Park, N.C.).

ORIENTATION AND FREQUENCY EFFECTS ON WHOLE ANIMALS ABSORPTION OF MICROWAVES: LETHALITY EXPERIMENTS. T. D. Hawkins (Dept. Microwave Res., Walter Reed Army Inst. Res., Washington, D. C.).

INSECT CONTROL POSSIBILITIES USING MICROWAVES AND LOWER FREQUENCY RF ENERGY. S. O. Nelson (U.S. Dept. Agriculture, Univ. Nebraska, Lincoln).

NERVE STIMULATION BY IMPLANTED DIODE. C. C. Johnson (Univ. Utah, Salt Lake City, Utah), J. L. Lords and M. A. Coombs.

LIQUID CRYSTAL FIBEROPTIC TEMPERATURE PROBE FOR THE MEASUREMENT OF ELECTROMAGNETIC POWER ABSORPTION IN TISSUE. C. C. Johnson (Univ. Utah, Salt Lake City, Utah), C. H. Durney and J. L. Lords.

ELECTROMAGNETIC FIELDS INDUCED INSIDE OF BIOLOGICAL BODIES. D. Livesay (Michigan State Univ., East Lansing) and Kun-Mu Chen.

MULTI-FREQUENCY ELECTROMAGNETIC THAWING OF FROZEN KIDNEYS. C. P. Burns (Eng. Sta., Georgia Inst. Technol., Atlanta) and C. E. Burdette.

SOME THEORY AND PRELIMINARY EXPERIMENTS ON MICROWAVE RADIOMETRY OF BIOLOGICAL SYSTEMS. J. Bigu del Blanco (Queen's Univ., Kingston, Ontario, Canada) and J. A. Tanner.

MICROWAVE SAFETY AND PROTECTION STANDARDS: PANEL DISCUSSION. Seminar theatre, Sheraton-Biltmore.

**** CONFERENCE ON PRECISION ELECTROMAGNETIC MEASUREMENTS.

Date: July 1-5, 1974.

Place: The Institution of Electrical Engineers, Savoy Place, London, England.

Sponsor: Royal Society; Institution of Electrical Engineers; Union Radio-Scientifique Internationale; The Institution of Electronic and Radio Engineers; The National Physical Laboratory; Scientific Manufacturers' Association.

Selected Bibliography of Papers to be Presented:

AN OPTICALLY LINKED TELEMETRY SYSTEM FOR USE WITH ELECTROMAGNETIC HAZARD PROBES. H. Bassen (Bur. Radiol. Hlth., Rockville, Maryland).

DETERMINATION OF RF POWER ABSORPTION IN MAN EXPOSED TO HF FIELDS BY THERMOGRAPHIC STUDIES ON SCALED PHANTOM MODELS. A. W. Guy (Univ. Washington Med. Sch., Seattle), M. Webb and J. C. Lin.

MEASUREMENT OF ABSORBED POWER PATTERNS IN THE HEAD AND EYES OF RABBITS EXPOSED TO TYPICAL MICROWAVE SOURCES. A. W. Guy (Univ. Washington Med. Sch., Seattle), J. C. Lin, P. Kramar and A. F. Emery.

SOME PROBLEMS IN USING ELECTRIC FIELD INTENSITY DURING INVESTIGATION OF BIOLOGICAL EFFECTS. H. R. Kucia-Korniewicz (Central Res. Inst. Labor Protect., Poland).

COMPARATIVE MEASUREMENT OF DIELECTRIC PROPERTIES OF FRESH MAMMALIAN TISSUES. J. C. Lin (Univ. Washington Sch. Med., Seattle), H. M. Grove and J. C. Sharp.

ON MEASUREMENTS OF THE ELECTROMAGNETIC FIELDS FOR HYGIENIC PURPOSES. J. Musil (Inst. Hygiene Epidemiol., Czechoslovakia).

VOLTAGE INDUCTION BY PULSE-SHAPED EM FIELDS ON

MEETINGS AND CONFERENCES

Biological Effects Electromagnetic
Radiation I(1), June 1974 and I(2),
September 1974

TRANSMISSION LINES, APPLICATION TO INTERFERENCE PROBLEMS IN ELECTRONIC SYSTEMS. H. Naito (Eidgenössische Technische Hochschule Zürich, Switzerland) and A. Shah.

INSTRUMENTATION SYSTEMS FOR LASER POWER AND ENERGY DETERMINATIONS FOR USE UNDER A UNITED STATES LASER REGULATORY PERFORMANCE STANDARD. R. W. Peterson (Bur. Radiol. Hlth., Rockville, Maryland).

THE AUTOMATION OF AN ELECTROMAGNETIC INTERFERENCE MEASUREMENT SYSTEM. C. Sorenson (The Singer Company, USA), B. Meyers and G. U. Sorger.

**** 19TH ANNUAL MEETING OF THE HEALTH PHYSICS SOCIETY.

Date: July 7-11, 1974

Place: Houston, Texas

Sponsor: Health Physics Society

Requests for Information: W. H. Parr, Physical Agents Branch/NIOSH, 1014 Broadway, Cincinnati, Ohio 45202

Selected Bibliography of Papers Presented:

HEATING PATTERNS INDUCED BY 2450 MHZ MICROWAVE RADIATION IN A TRILAYERED SPHERICAL PHANTOM.

D. L. Conover (Natl. Inst. Occupational Safety and Hlth., Cincinnati, Ohio) and R. J. Vetter.

MICROWAVE LEAKAGE IN HOME MICROWAVE OVENS. STATUS REPORT. M. C. Wukasch (Texas State Dept. Hlth., Div. Occupational Hlth. and Radiation Control, Austin) and J. F. Thiel.

ASSESSING THE POTENTIAL FOR EXPOSURE TO HAZARDOUS LEVELS OF MICROWAVE RADIATION FROM HIGH POWER SOURCES. N. N. Hankin (Off. Radiation Programs, EPA, Silver Springs, Md.), R. A. Tell and D. E. Janes.

THE IN VIVO EFFECTS OF 2.45 GHZ MICROWAVE RADIATION ON RABBIT SERUM COMPONENTS. R. T. Wangemann (Laser-Microwave Div., US Army Environ. Hygiene Agency, Aberdeen Proving Ground, Md.).

PERMISSIBLE LEVELS OF EXPOSURE TO MICROWAVE RADIATION. S. K. Ghosh (Dept. Hlth. Welfare, Radiation Protect. Bur., Ottawa, Canada) and A. K. DasGupta.

THE NEW HEALTH AND SAFETY ACT AS IT RELATES TO OCCUPATIONAL RADIATION EXPOSURE. F. H. Ryer (US Dept. Labor, Washington D. C.).

**** 5TH INTERNATIONAL CONGRESS OF RADIATION RESEARCH.

Date: July 14-20, 1974

Place: Seattle, Washington

Sponsor: International Association for Radiation Research; Radiation Research Society

Requests for Information: Dr. W. K. Sinclair, Secretary-general, Argonne National Laboratory, Argonne, Illinois 60439.

Selected Bibliography of Papers Presented:

BEHAVIORAL SUPPRESSION BY 383 MHZ RADIATION. R. J. Cunitz (Bur. Radiol. Hlth., Rockville, Md.), W. D. Galloway and C. M. Bernau.

SURVIVAL OF DROSOPHILA EGGS EXPOSED TO MICROWAVE ENERGY AND TO HEAT. F. A. Anderson (Bur. Radiol. Hlth., Rockville, Md.) and T. L. Pay.

MICROWAVE CAVITY IRRADIATION DOSIMETRY. W. P. Edwards (Bur. Radiol. Hlth., Rockville, Md.) and H. S. Ho.

**** 1974 IEEE INTERNATIONAL SYMPOSIUM ON ELECTROMAGNETIC COMPATIBILITY.

Date: July 16-18, 1974

Place: San Francisco, California

Sponsor: Institute of Electrical and Electronics Engineers (G-EMC)

Requests for Information: IEEE, Order Division, 345 E. 47th Street, New York, New York 10017

Selected Bibliography of Papers Presented:

MICROWAVE POWER DENSITY MEASUREMENTS IN THE PRESENCE OF BIOLOGICAL SPECIMENS OF SIZE COMPARABLE TO THE FREE SPACE WAVELENGTH OF THE IMPOSED RADIATION. J. Bigu del Blanco (Dept. Anatomy, Queens Univ., Kingston, Canada).

ABSENCE OF HEART-RATE EFFECTS IN ISOLATED FROG HEART WITH PULSED MODULATED LOW LEVEL MICROWAVE ENERGY. C. Cain (Dept. Electrical Engineering, Univ. Illinois, Urbana).

THE EFFECTS OF FM AND TV BROADCAST STATIONS UPON CARDIAC PACEMAKERS. M. D. Shepherd (Univ. California, San Francisco Medical Center).

**** THE PHYSICS OF NONIONIZING RADIATION.

Date: July 21-26, 1974.

Place: University of Colorado, Boulder, Colorado

Sponsor: American Association of Physicists in Medicine Summer School

MEETINGS AND CONFERENCES

Requests for Information: American Association of Physicists in Medicine Summer School, University of Colorado, Boulder, Colorado.

Selected Bibliography of Papers to be Presented:

CLINICAL APPLICATIONS AND BIO-EFFECTS OF MICROWAVES. F. S. Barnes (Univ. Colorado, Boulder) and F. Cenkovich.

FUNDAMENTAL PRINCIPLES OF MICROWAVES. E. L. Chaney (Univ. Colorado Med. Ctr., Denver).

**** BIOLOGICAL EFFECTS, HAZARDS AND MEDICAL USES OF NON-IONIZING RADIATIONS.

Date: July 29-August 2, 1974.

Place: Massachusetts Institute of Technology, Dept. Mechanical Engineering, Cambridge, Mass.

Sponsor: Department of Mechanical Engineering, M.I.T.; Harvard-M.I.T. Program in Health Sciences and Technology.

Requests for Information: Director of the Summer Session, Room E19-356, Massachusetts Inst. Technology, Cambridge, Massachusetts 02139.

Topics to be Covered Include: Physical characteristics and field measurement, dosimetry, electrical properties of biological tissues in constant and varying fields, absorption, thermal effects, non-thermal effects; results and mechanisms in blood, eye, testes, malignant tumors, growth; applications in therapy; health hazards of radar, microwave ovens and safety standards.

**** 27TH ANNUAL CONFERENCE ON ENGINEERING IN MEDICINE AND BIOLOGY.

Date: October 6-10, 1974

Place: Philadelphia, Pennsylvania

Sponsor: Alliance for Engineering in Medicine and Biology

Requests for Information: Hun Sun, Drexel University, Philadelphia, Pennsylvania 19104

Selected Bibliography of Papers to be Presented:

MICROWAVE RADIOMETRY: A NEW TECHNIQUE TO INVESTIGATE THE INTERACTIONS OF MW RADIATION WITH LIVING SYSTEMS. J. Bigu del Blanco (Queens Univ., Kingston, Ontario, Canada).

MEASUREMENT OF CARDIAC PACEMAKER SUSCEPTIBILITY TO ELECTROMAGNETIC FIELDS. J. C. Toler (Georgia Inst. Technol., Atlanta) and W. H. Fleming.

**** WESTERN INDUSTRIAL HEALTH CONFERENCE

Date: October 10-12, 1974

Place: Los Angeles, California

Sponsor: Amer. Industrial Hygiene Assn; Health Phys. Society; Amer. Conference of Govt. Industrial Hygiene; Western Industrial Medical Assn.; Western Assn. of Industrial Nurses

Requests for Information: B. H. Bravinder, Box 201, Alamo, California 94507

**** 7TH AUSTRALIAN INSTITUTE OF NUCLEAR SCIENCE AND ENGINEERING (AINSE) RADIATION CHEMISTRY MEETING

Date: October 14-16, 1974

Place: Lucas Heights, Australia

Sponsor: AINSE

Requests for Information: AINSE, Lucas Heights, Australia

**** INTERNATIONAL SYMPOSIUM ON RADIATION PHYSICS.

Date: December 4, 1974

Place: Calcutta, India

Sponsor: Dept. of Physics, 93/1 Acharya Prafulla

Requests for Information: A. M. Ghose, Dept. of Physics, 93/1 Acharya Prafulla, Chandra Road, Calcutta 700-009, India

**** 1ST ASIAN REGIONAL CONGRESS OF RADIATION PROTECTION.

Date: December 15-20, 1974

Place: Bombay, India

Sponsor: Intl. Radiation Protection Association

Requests for Information: S. D. Soman, Modular Laboratories, Room 1-216H, Bhabha Atomic Research Center, Bombay 400-085 India

CURRENT LITERATURE

Biological Effects Electromagnetic
Radiation I(1), June 1974 and I(2),
September 1974

- 0001 EFFECT OF INDUCTOTHERMY ON PANCREATIC
FUNCTION. (Rus.) Korepanov, A. M.
(Izhevsk Med. Inst., USSR). *Vopr Kurortol Fizioter
Lech Fiz Kult* 36:340-343, 1971.

Inductothermy was used to treat 365 patients, aged 18-50 yr, who had chronic cholangiohepatitis (obstructive jaundice (200), chronic gastritis associated with hypo- or achlorhydria (90), duodenal ulcers (40), diabetes mellitus (18) and chronic colitis (8). Except for 23 patients who received thermal doses, all patients were given oligothermal doses. Exposure time was 30 min for single doses and ranged from 20 to 60 min during courses of therapy. Under basal conditions and after stimulation of pancreatic activity by instillation of 30 ml 0.25% HCl through a duodenal sound, inductothermy significantly increased the volume of duodenal juice and its bicarbonate concentration and slightly increased its enzyme activity. Thermal doses, given to 23 patients, suppressed secretion and reduced enzyme activities in most patients. Courses of inductothermy (10-12 exposures), administered to 92 patients, produced symptomatic improvement in many patients, reduced the size of the liver in all 58 patients with hepatomegaly, and caused disappearance of mucus and WBC from the bile in 32 of 49 patients. Bicarbonate concentrations and lipolytic activity of the duodenal juice increased significantly. Significant decreases occurred in blood and urinary diastase values during therapy, but lipase activities did not change appreciably. Studies of the exocrine function of the pancreas performed on 53 patients, 18 of whom had diabetes mellitus, showed that inductothermy significantly increased blood sugar levels in patients with hypoglycemia and significantly decreased blood sugar levels in diabetics. No appreciable changes occurred in the glucose tolerance curves of the 30 patients tested. On the basis of these findings it is recommended that inductothermy in oligothermic doses be used in the treatment of patients with gastrointestinal disorders associated with disturbances in pancreatic function. (No references)

- 0002 USE OF CHEMICAL SUBSTANCE IN SUPERHIGH
FREQUENCY ELECTROMAGNETIC RADIATION.
(LITERATURE REVIEW). (Rus.) Koldaev, V. M. (I. P. Pavlov Med. Inst., Ryazan, USSR). *Farmakol Toksikol* 35:505-507, 1972.

Investigations have shown that radioprotective agents, biogenic amines, agents producing methemoglobin, and stimulants decreased the survival times of experimental animals exposed to SHF radiation, whereas chlorpromazine and sodium barbital increased the survival time. Administration of general and local anesthetics prevented low-intensity SHF radiation from affecting cardiac rhythm. Sublethal doses of epinephrine, strychnine, and pentylene-tetrazole, administered after irradiation, decreased the number of animals that died, and pyridoxine

improved circulation when animals were irradiated with 80 mW/cm². Although there is no specific treatment for damage produced by SHF radiation, camphor, valerian and bromine, glucose and ascorbic acid, and B vitamins have been used to treat acute damage in man while gentian infusion, strychnine, securinine, meprobamate, calcium gluconate, and others have been employed to treat chronic forms. Recurrences have sometimes developed 2 months to 1 yr later. Drugs used to diagnose damage produced by SHF radiation include those which stimulate various parts of the central nervous system, ergot derivatives, atropine, and others. (24 references)

- 0003 THERMAL AND ATHERMAL EFFECTS OF MICROWAVE
RADIATION ON THE ACTIVITY OF GLUCOSE-6-
PHOSPHATE DEHYDROGENASE IN HUMAN BLOOD. (E.)
Belkhole, M. L. (Radiation Protection Bureau, Hlth.
Protection Br., Dept. Natl. Health Welfare, Ottawa,
Canada), D. L. Johnson and A. M. Muc. *Health Phys*
26:45-51, 1974.

Human blood and yeast glucose-6-phosphate dehydrogenase were treated with 2.8 GHz microwave radiation (CW, 1kHz square wave modulation) at an incident power density of between 500 mW/cm² and 1000 mW/cm². The power absorbed was observed to be 230 ± 70 mW/cm³. This corresponds to absorbed energies of 35 and 62 J/cm³ for the two treatment times used. Treatments were carried out at fixed temperatures of 37°, 46.7° and 49.7° C in such a way as to distinguish between thermal and athermal effects on the activity of glucose-6-phosphate dehydrogenase. Thermally induced reductions in relative activity of up to 80%, which were dependent on treatment period, were observed. The observed average athermal effect on the relative activity was $(0.4 \pm 1.8)\%$. This is not statistically significant. Thus, no athermal effect of microwave radiation on the activity of glucose-6-phosphate dehydrogenase was observed.

- 0004 DOSIMETRY STUDIES ON A UHF CAVITY EXPO-
SURE CHAMBER FOR RODENTS. (E.) Guy, A. W.
(U. Washington Sch. Med., Seattle) and S. F. Korbel.
Proc Microwave Power Symp (Inst. Microwave Power,
Canada) May 1972, p 180-187.

The thermographic dosimetry technique was used to study the relationship between cavity fields and absorbed power characteristics of rats in a cavity-type exposure chamber. Cavity resonance was approximately 500 MHz with field patterns corresponding to degenerate TE₁₀₅ and TE₅₀₁ modes. The measured effective power density of 1 mW/cm² in the chamber was equivalent to an input power of 10 watts. Typically, the peak absorbed power density for 227 g phantom rats ranged from 3-70 mW/cm³; in extreme cases it was as low as 0.35 mW/cm³ and as high as 185 mW/cm³, depending on the position and posture of the rats. In most positions simulating the

drinking rate, the peak absorption was very high in the limbs and nose of the phantom.

- 0005 MICROWAVE DEFREEZING OF CANINE KIDNEYS.
(E.) Rajotte, R. (Surg. Med. Res. Inst.,
U. Alberta, Edmonton, Canada), W. A. G. Voss,
J. B. Dossetor and C. R. Stiller. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada)
May 1972, p 178-179.

The use of fluorocarbon to progressively cool the canine kidney below the freezing point of water was investigated, using the vasculature to carry the cooling agent and microwave heating to thaw the organ. Freezing rates of 2 C/min were achieved. It was more difficult to achieve uniformity during defreezing. The fluorocarbon-loaded organ absorbs power rapidly at 2.45 GHz. For 50 g kidneys heated to 23 C, the internal temperature gradients were not more than 4 C, but with larger kidneys there were variations of ± 10 C. Disproportionate rapid heating of the ureter and slow heating of the renal papillae were occasional problems. Reimplantation of thawed kidneys was not a functional success.

- 0006 THE DIFFERENTIAL TEMPERATURE RISE AT HOT SPOTS GENERATED IN LOSSY SPHERES BY ELECTROMAGNETIC WAVES. (E.) Kritikos, H. (Moore Sch. Electric. Eng., U. Pennsylvania, Philadelphia) and H. Schwan. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) May 1972, p 194-195.

The heat potential generated by electromagnetic waves in a multilayered lossy sphere was investigated in the frequency region 10-10,000 MHz. The multilayer sphere was modeled after a human head with the layers having the electrical characteristics in succession of skin, fat, bone, and tissue. Small spheres (5 cm in radius) in the region 400-2800 MHz have hot spots generated near their center. Larger spheres (10 cm in radius) do not. The size of the hot spots is approximately a spherical region of diameter equal to a half wavelength. For the case of a 5-cm sphere, an incident field of 10 mW/cm², at 1000 MHz frequency, and a hot spot of 1 cm in radius, the maximum temperature rise is 0.580 C over the ambient. The temperature rise is a strong function of blood flow. For no blood flow the temperature rise is 0.90 C and for five times normal blood flow it is 0.210 C.

- 0007 MICROWAVE INTERACTION WITH THE AUDITORY SYSTEMS OF HUMANS AND CATS. (E.) Guy, A. W. (U. Washington Sch. Med., Seattle), E. M. Taylor, B. Ashleman and H. C. Lin. *Proc Int Microwave Symp* (IEEE, New York City, N.Y.) June 1973, p 321-323.

Recordings from elements of the auditory system of cats in response to pulsed microwaves, as well as

determinations of thresholds of audibility of humans to the pulses, indicate that an auditory sensation may be elicited by pulse energies $> 20 \mu\text{J}/\text{cm}^2$, regardless of average or peak power. Responses elicited in the round-window of the cat cochlea by radiation directly over the inferior temporal area had the same form as those elicited by acoustic click stimulus. By positioning the applicator at a variety of sites removed from the immediate auditory area, a unique series of potentials with increasing amplitudes was obtained; these potentials were produced by radiation in the X as well as the S band. The pulse characteristics for eliciting auditory effects in the cat are given for three different frequencies. Also shown are the thresholds of auditory responses in humans to 2450 MHz radiation at 3 pulses/sec. Significantly, the threshold energy for detection by one subject with normal hearing was approximately 1/3 to 1/4 of that required for another subject with sensorineural hearing impairment. Each individual pulse was heard as a distinct click with the sound originating within and near the back of the head. Short pulse trains were heard as chirps with tone corresponding to the pulse recurrence rate.

- 0008 MICROWAVE EFFECTS ON CENTRAL NERVOUS SYSTEM ATTRIBUTED TO THERMAL FACTORS.
(E.) Taylor, E. M. (U. Washington, Seattle), A. W. Guy, B. Ashleman, and J. C. Lin. *Proc Int Microwave Symp* (IEEE, New York City, N.Y.) June 1973, p 316-317.

Elevation of thalamic temperature by the circulation of heated fluid through an exchanger applied to the base of the cat skull resulted in evoked potential changes comparable to those produced by microwave heating of the same magnitude (10W and 15W incident, 918 MHz continuous wave). In both cases the changes were in the nature of decreased latency of late components of the evoked potential. Nervous system changes resulting from microwave illumination heating were counteracted or reversed with concurrent cooling of the affected tissue. These results are evidence that the microwave effect on the central nervous system is a thermal phenomenon.

- 0009 EFFECT OF 2450 MHz MICROWAVE FIELDS ON PERIPHERAL NERVES. (E.) Chou, C. K. (U. Washington Sch. Med., Seattle) and A. W. Guy. *Proc Int Microwave Symp* (IEEE, New York City, N.Y.) June 1973, p 318-320.

There was no significant change in amplitude, conduction velocity, or excitability of frog and cat nerves exposed to continuous and pulsed 2450 MHz fields in a waveguide filled with temperature-controlled Ringer's solution. Absorbed power densities varied from 0.003 to 1.7 W/cc for continuous wave fields and 0.3 to 30 W/cc peak for pulsed fields. Frog action potential amplitude and latency were degraded at about 35 C, but

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these temperature-sensitive characteristics were reversible. A temperature of 46 C caused irreversible damage to the cat nerve. When double stimulation pulses 1.2 millisecond apart were used, the response due to the second pulse was in the relative refractory period of the first response. The characteristics of the second response were more sensitive to temperature changes. This indicates that a slight microwave-induced temperature rise in the peripheral nerve might alter firing patterns of neurons in the CNS.

- 0010 LENS OPACITIES IN EYES OF RABBITS FOLLOWING REPEATED DAILY IRRADIATION AT 2.45 GHz. (E.) Carpenter, R. L. (Northeastern Radiol. Hlth. Lab., Winchester, Mass.), E. S. Ferri, and G. J. Hagan. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) May 1972, p 167-168.

The development of lens opacities was studied in New Zealand White rabbits irradiated at 2.45 GHz 1 hr daily for 20 consecutive days. Six groups of 10 animals were irradiated at different power densities. Opacity formation in these groups occurred as follows: at 50 mW/cm², none; at 80 mW/cm², one; at 90 mW/cm², one; at 100 mW/cm², five; at 110 mW/cm², four; and at 120 mW/cm², eight. No animal irradiated once at 102 mW/cm² for up to 5-1/2 hr developed lens opacity. Thus, this microwave dose represents a power density well below the cataractogenic threshold for acute exposure of the rabbit eye, but daily repetition can cause lens opacities to develop.

- 0011 PSYCHOPHYSICAL DATA ON THE RF HEARING EFFECT. (E.) Frey, A. H. (Randomline Inc., Willow Grove, Pa.) and R. Messenger. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) May 1972, p 169-173.

A series of psychophysical studies was carried out with humans in a radiofrequency (RF) anechoic chamber. The RF carrier frequency was 1.245 GHz, and all energy measurements were taken with a half wave dipole located in the center of a subject's head. The maximum average power density at the head was 1.3 mW/cm². Perceived loudness, determined by the magnitude estimation technique, was a function of peak power density. The threshold peak power density calculated from test data is 80 mW/cm². A band of optimal pulse widths seems to exist for perception. There are also RF modulation characteristics which yield the perception of complex pitch. The data indicate that the RF hearing phenomenon is not due to a radiation pressure effect.

- 0012 THEORETICAL AND EXPERIMENTAL STUDIES OF MICROWAVE INDUCED CATARACTS IN RABBITS. (E.) Kramer, P. (U. Washington, Seattle), A. F. Emery, A. W. Guy and J. C. Lin. *Proc Int Microwave Symp* (IEEE, New York City, N.Y.) June 1973, p 265-267.

Power deposition patterns, temperature distribution patterns, and cataractogenesis thresholds were established in the eyes of rabbits exposed to localized near zone 2450 MHz radiation. The absorbed power distribution reached peak values in the vitreous body at about half-way between the lens and the retina with a mean of 0.92 mW/g for each mW/cm² incident power. In all cases maximum temperatures were localized in the retrolental area near the posterior surface of the lens. After a sub-threshold radiation dose of 100 mW/cm² for 60 min, the maximum temperature was 40.7 C. Radiation at 300 mW/cm² for 30 min indicated an inordinate rise to 46 C and a corneal temperature of 37.7 C. The earliest lens damages, consisting of posterior cortical banding and small vacuoles in the region of the posterior suture line, appeared within the 1st wk after exposure. These changes showed no progression at the lower level of irradiation. At the higher level the vacuoles increased in number and a distinct, well-circumscribed subcapsular opacity developed. These results are in good agreement with theoretical predictions.

- 0013 FURTHER EXPERIMENTS SEEKING EVIDENCE OF NONTHERMAL BIOLOGICAL EFFECTS OF MICROWAVE RADIATION. (E.) Liu, L. M. (Electr. Eng. Dept., Washington U., St. Louis, Mo.), G. W. Skewes, G. A. Lindauer, and F. J. Rosenbaum. *Proc Int Microwave Symp* (IEEE, New York City, N.Y.) June 1973, p 333-334.

Carpenter and Livstone's microwave experiments on beetle pupae were repeated and extended. The incidence of abnormality increased more than 3-fold with irradiation while the death rate remained essentially unchanged. The percentage of G3 abnormalities showed a particularly dramatic difference between experimental and control groups. The incidence of teratological damage was independent of specimen orientation, irradiation power level (10 mW-20mW), or whether the microwave power was pulse or continuous wave (CW). The incidence did depend on the energy absorbed and the pupa age when irradiated, as shown by results for a group receiving 10 mW for 2 hr vs 10 mW for 4 hr and by comparison of 2- and 5-day-old pupae irradiated at 20 mW CW for 2 hr.

- 0014 EFFECTS OF MICROWAVE IRRADIATION ON ENZYMES AND METABOLITES IN MOUSE BRAIN. (E.) Nelson, S. R. (U. Kansas Med. Ctr., Kansas City). *Radiat Res* 55:153-159, 1973.

After decapitation and exposure of the mouse head to microwave radiation, seven of the eight brain enzymes (hexokinase, aldolase, pyruvate kinase, P-fructokinase, lactate dehydrogenase, adenylate kinase, P-creatine kinase, and phosphorylase) studied were inactivated. The remaining enzyme, myokinase, retained about 10% of control activity. Brain metabolite levels were also altered by microwave radiation and these changes were used indirectly to

obtain information about the sensitivity of enzymes to heat inactivation. ATP hydrolyzing enzymes were relatively resistant to heat since inactivation was delayed long enough for half the available ATP to be used. P-creatine kinase was inactivated early during microwave treatment since P-creatine, usually depleted in seconds, was reduced only 30% in the anoxic brain. Hexokinase appeared most sensitive to heat since glucose, rapidly used in the anoxic brain, remained at control levels after microwave irradiation. Glycogen decrease and G-6-P elevation indicated brain phosphorylase was not immediately inactivated in the experimental mice. Low lactate levels in the anoxic, treated brains showed that the flow of glycolytic intermediates was quickly blocked at one or more steps between G-6-P and lactate. Since fructose diphosphate was depleted in brain from the irradiated, anoxic head, aldolase was resistant to early inactivation. The metabolite changes observed after the decapitated heads were irradiated were also observed when the heads of intact mice were treated, and the changes occurred in both cortex and subcortex of these mice.

- 0015 EFFECTS OF MICROWAVE RADIATION ON ENZYMES.
(E.) Langley, J. B. (Georgia Inst. Technol., Atlanta), E. K. Yeagers, A. P. Sheppard, and G. K. Huddleston. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) Sept. 1973, 3B4/1-3B4/2.

Experiments were conducted to investigate the effects of microwave heating on lysozyme and trypsin as opposed to conventional heating. In one of the two experimental systems, the heating apparatus was a glass tube passing through a section of S-band waveguide parallel to the electric field. Microwave power was supplied from a continuous wave (CW) magnetron through a variable attenuator. A thermistor in the glass tube measured the temperature of the circulating liquid, with thermistor output controlling the a.c. power to a resistance heater in the other system. Through the a.c. power control system, the two volumes of enzyme solution underwent the same thermal cycle for the same amount of time. No statistically significant differences in deactivation were noted between enzyme solutions heated by microwave power and those heated by conventional means.

- 0016 MICROWAVE BIOLOGICAL EFFECTS UNDER REPRODUCIBLE DOSIMETRIC AND ENVIRONMENTAL CONDITIONS. (E.) Ginns, E. I. (U.S. Dept. Hlth., Educ. Welfare, Rockville, Md.), R. Rugh, H. S. Ho., W. Leach, L. Gillespie, R. Budd, and D. G. Hazzard. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) Sept. 1973, p 2B2/1-2B2/2.

The biological effects of 2.45 GHz microwave energy on CFI mice were investigated by exposing the mice to a power density of 100 mW/cm² in an environmentally controlled waveguide irradiation facility. Preliminary results suggest that as the Temperature-Humidity

Index increases, there is a decrease in the lethal dose of microwave energy (THI, 69-83; absorbed dose, 160-85 cal/g; forward power, 7.0 watts) to 1- to 2-month-old mice. Results of testing juvenile and adult mice for sterility through two or three matings indicated that microwave radiation causes reduced litter size. *In utero* anomalies were determined by irradiating (absorbed doses, 6.1-9.3 cal/g) time-mated mice on the 7th to 13th day of gestation. Fetuses dissected before delivery showed blood vessel dilation, hemorrhaging, stunting, and resorption plus evidence of exencephaly.

- 0017 CYTOGENETIC EFFECT OF MICROWAVE RADIATION ON CHINESE HAMSTERS. (E.) Everts, J. M. (Environmental Protection Agency, Eastern Environ. Radiat. Lab., Montgomery, Alabama), W. A. Herman, M. C. Colvin, C. R. Porter, and C. R. Philips. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) May 1972, p 139-142.

To determine whether there is a cytogenetic effect of microwaves, hamsters were irradiated in a calibrated anechoic chamber for varying time intervals up to 2 min at 200 mW/cm². Tissue cultures were prepared from kidney, lung, and thyroid tissue, scored for chromosome abnormalities after a 74 hr growth period, and compared with tissues from control animals. The overall average percentage of chromosome aberration increased from approximately 2.5% at 15-sec exposure to approximately 5.5% at 60-sec exposure and then dropped to about 3.5% at 12-sec exposure. This general trend held true for each tissue observed although the maximum percentage aberration varied slightly with different exposure times. The average percentage aberration in sham irradiated animals was about 10% for all exposure times. Rectal temperature increased significantly at the 120-sec exposure. The types of aberrations observed included chromatid breaks, chromosome breaks, dicentric and fragments, rings, reconstitutions, and endo-reduplications. Whether such damage is primarily thermal in nature is uncertain, but the heat produced undoubtedly contributed to the observed effects.

- 0018 NON-CONTACT DETERMINATION OF TEMPERATURE CHANGES IN MICE DURING MICROWAVE IRRADIATION. (E.) Rotkowska, D. (Inst. Biophysics, Czechoslovak Acad. Sci., Brno). *Physiol Bohemoslov* 22(4):359-363, 1973.

Hairless male BFU mice were irradiated with microwaves at an output density of 260 mW/cm² (frequency 2,450 c/s, wavelength 12.5 cm). An AGA 680 thermovision camera was used to measure changes in their body temperature immediately following irradiation. Five minutes of irradiation raised the rectal temperatures of the mice an average of 2.6 C. The temperature increase varied in different parts of the body, being especially marked in the region of the heart and liver. The course of the tempera-

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ture changes in the region of the tail during microwave irradiation indicated that the tail participates in the regulation of heat output in mice.

- 0019 GASTROINTESTINAL MOTOR ACTIVITY FOLLOWING EXPOSURE TO A HIGH-FREQUENCY ELECTRIC FIELD. (E.) Tansy, M. F. (Dept. Physiol., Temple U. Sch. Dentistry, Philadelphia, Pa.), F. M. Kendall, J. Chryzanowski, F. J. Hohenleitner and A. R. Kall. *Experientia* 27:1431-1432, 1971.

Adult male Sprague-Dawley rats were exposed for 30 minutes to a 60 MHz electric field between a pair of large condenser plates. The acetylcholine responsiveness of strips of their intestinal muscles in an isolated tissue bath was then evaluated, as were the differences in the incorporation of Evans Blue dye by various portions of the gastrointestinal tract at different intervals following exposure to the field. The muscle strips from the exposed animals showed a greatly increased strength of contraction in response to acetylcholine; this response persisted for 5 days following exposure. The colonic muscle strips from the exposed animals showed a decreased contractile response to acetylcholine. Two to 3 hours after exposure, the stomachs of the rats lost significantly more dye than did the stomachs of nonexposed controls. The colons of the exposed animals collected more dye than did those of the controls.

- 0020 DEPRESSION OF PHAGOCYTOSIS: A NON-THERMAL EFFECT OF MICROWAVE RADIATION AS A POTENTIAL HAZARD TO HEALTH. (E.) Mayers, C. P. (Dept. Path., U. Edinburgh, Scotland) and J. A. Habeshaw. *Int J Radiat Biol* 24(5):449-461, 1973.

The widespread use of microwave equipment presents potential hazards to health from inadvertent exposure. The hazards due to the heating effect of microwaves are well recognized. Recent evidence suggests that microwave radiation produces other biological effects that are not in any way due to heating. Experiments were performed to investigate the non-thermal effects of microwaves on the process of phagocytosis. Monolayer cultures of mouse macrophages on cover-slips were perfused with suspensions of human red blood cells while being exposed to microwave radiation of 2450 MHz frequency, at a power level of 50 mW/cm², under strict temperature control. Comparison of the phagocytic indices of the irradiated cultures with unirradiated control cultures demonstrated a marked depression of phagocytic activity. Further investigation showed that macrophage phagocytic activity was restored to normal if the radiation was discontinued. Relatively long periods of exposure to microwaves might be expected to affect the mechanism of cell-mediated immunity in superficial tissues, with consequent increased susceptibility to infections and suppression of the immunological surveillance mechanisms which might allow aberrant cell forms to develop.

- 0021 UNCERTAINTIES IN THE EVALUATION OF THE BIOLOGICAL EFFECTS OF MICROWAVE AND RADIOFREQUENCY RADIATION. (E.) Cleary, S. F. (Dept. Biophysics, Virginia Commonwealth U., Richmond). *Health Phys* 25:387-404, 1973.

Evaluation of the effects of microwave or radio-frequency (RF) radiation on biological systems and the risks attendant upon human exposure to such radiations is complicated by the complex nature of microwave absorption in tissue and the lack of molecular interaction mechanisms. The development of more sophisticated methods of dosimetry should lead to a better correlation between the parameters of the microwave field and the energy distribution within the absorber. Nonuniformities in the pattern of energy absorption and the consequent temperature variations within a body may play a significant role in the induction of low intensity reversible microwave effects. The concept of evaluating biological effects on the basis of average radiation-induced temperature increases is therefore subject to question. A review of microscopic or molecular interaction mechanisms indicates that the most probable radiation-induced alterations would involve the reversible disruption of systems of weak cooperative bonding leading to conformational changes in molecules or molecular assemblages. Although such effects might be dependent upon the wavelength of the radiation, there is no direct evidence for nonthermal molecular interactions in biological systems. It is possible that thermally enhanced molecular interactions may occur at relatively low radiation intensities. Such effects would not necessarily involve significant gross body heating and, as such, would provide a molecular basis for the suspected role of microwave or RF-induced nonuniform temperatures rises in biological systems.

- 0022 MICROWAVE RADIATION HAZARDS AROUND LARGE MICROWAVE ANTENNA. (E.) Klascius, A. (Jet Propulsion Lab., California Inst. Technol., Pasadena). *Amer Ind Hyg Assoc J* 34(3):97-101, 1973.

The microwave radiation hazards associated with the use of large antennas become increasingly more dangerous to personnel as the transmitters go to ever higher powers. The near field area is of the greatest concern in that it may contain spill-over from subreflectors and reflections from nearby objects. Any curved or flat surface can collect microwave energy and reflect it. When an electromagnetic wave hits the surface of the human body, part of the energy is reflected and the remainder is transformed to heat within the tissues. Low level electromagnetic radiation causes difficulties that are primarily of a neurological nature, and nonthermal effects may cause changes in interneuron connections, the inactivation of certain viruses, changes in the growth and infective properties of bacteria, and changes in the course of cell division. Energy from spill over and side lobes coming from the antenna arriving at the same point in space in the same phase could result in energy densities two to four times

greater than would normally be there. A cranium structure located in such a field could act as a resonant cavity to absorb this energy to an even higher concentration. Centimeter wave meeting in phase will reinforce each other and create hot spots of microwave energy; these hot spots could reach the levels encountered inside a microwave oven. This phenomenon has been measured in front of and around several 26-meter antennas. The hot spots which were found will be the determining factor in delineating safe areas for personnel to work. Better techniques and instruments to measure these fields are needed for the evaluation of hazard areas.

- 0023 ELECTROMAGNETIC INTERACTIONS WITH BIOLOGICAL MATERIALS. (E.) Guy, A. W. (Sch. Med., U. Washington, Seattle). *Proc G-AP Int Symposium*, August 22-24, 1973, p 192-195.

Electromagnetic (EM) energy can produce biological damage through tissue heating at incident power levels of greater than 100 mW/cm². Studies in Eastern Europe and the Soviet Union have also indicated that thermal or athermal effects, especially on the central nervous system, might be produced by much lower power levels. Thus, in these countries, the safety standard for continuous 8 hour microwave exposure is 10 µW/cm², as opposed to 10 mW/cm² in the United States. The effects of low level EM radiation remain a subject of controversy in the United States. The fields induced in tissues by outside EM sources are complex functions of the types of sources, frequency, and subject size, and they may differ by many orders of magnitude depending on exposure conditions. Above 200 MHz, the combination of curved surfaces and high dielectric constant to tissues can produce very high localized and frequency dependent internal absorption deep in the tissues; below 200 MHz, the absorbed power in exposed subjects drops sharply with frequency. Internal fields and power absorption density may be directly measured *in vivo* by implanted electromagnetically transparent probes or indirectly measured in electrically equivalent phantom models of the subject and in the bodies of sacrificed animals. Measurements by these methods have shown power absorption density thresholds for various physical and psychological changes in humans and animals.

- 0024 MICROWAVE OVEN RADIATIONS: INFORMATION PAPER. (E.) Davis, J. A. (Flight Standards Technical Div., Dept. Transportation, Oklahoma City). *Engineering Report AAC-213-7 (73-749-130A)*, 1973.

The tolerance of the body to the effects of microwave radiation depends on the amount of blood flow in the exposed area. Examples of low tolerance parts of the body include the eyes and testes; high intensity exposure to microwave energy can cause cataracts. Damage is likely to occur at power

densities above 100 mW/cm² for whole body exposure for a time period of 6 minutes or longer; the American National Standards Institute has specified a maximum level of 10 mW/cm² for personnel exposure for 6 minutes or longer. Microwaves are also capable of inhibiting the action of demand pacemakers; if the heart should require stimulation while the pacemaker is inhibited by microwaves, the pacemaker would fail to pulse. The compatibility of pacemakers and microwave ovens depends on limiting microwave radiations and reducing the susceptibility of the pacemakers. According to federal standards, microwave ovens manufactured after October 6, 1971 may not emit radiation in excess of 1 mW/cm² prior to sales nor radiation in excess of 5 mW/cm² throughout the useful life of the oven. Each oven must have a minimum of two safety interlocks, one of which must be concealed. The accumulation of dirt may also increase radiation hazards from microwave ovens. Present production model microwave ovens are equipped with door seals and interlock systems to prevent leakage. Guidelines are presented for the engineering evaluation of aircraft microwave oven installations.

- 0025 DUODENAL ULCER IN PERSONS OCCUPATIONALLY EXPOSED TO MICROWAVE RADIATION. (E.) Wroblewski, T. E. (Dept. Gen. Exp. Path., Med. Acad., Warsaw, Poland), K. Zarzecki and R. Denisiewicz. *Mater Med Pol* 5:209-212, 1973.

Studies were conducted on 93 patients with alimentary tract disorders who had been occupationally exposed to microwave radiation at densities of 10 to 100 mW/cm². Duodenal ulcers were found in 38% of these patients, with the greatest number of cases being found among patients aged 21 to 31 years who had been exposed to microwave radiation for 1 to 11 years. Neurotic symptoms were common among the patients with duodenal ulcer. The data indicate that vegetative neurosis plays an important role in the development of duodenal ulcer in persons exposed to high frequency radiation for long periods of time. The data also support the contention that microwave radiation causes a state of hypervagotonia, which plays an important role in the pathogenesis of duodenal ulcer.

- 0026 MICROWAVE HEATING OF THE UTERINE WALL DURING PARTURITION. (E.) Daels, J. (Dept. Obstetrics Gynecol., Marie Middelares Clinic, Ghent, Belgium). *Obstet Gynecol* 42(1): 76-79, 1973.

Microwave radiation at a dose of 80 to 100 MHz was applied to the uterine wall of 1000 patients during parturition. Of these patients, 962 reported a good analgesic effect in conjunction with an agreeable sensation of relaxation; 38 patients experienced only moderate attenuation. The microwave irradiation also significantly shortened the average duration of the dilation period during parturition. This shortening effect amounted to 108

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minutes for primiparas and 43 minutes for multiparas, with the acceleration being localized mainly in the latent phase. The microwave treatment had no adverse effects on the neonate, and no important complications of the parturition or postpartum period were noted. The Apgar scores were significantly better among the irradiated patients than among a control group of patients.

0027 THE EFFECT OF CHRONIC, LOW-LEVEL MICRO-WAVE RADIATION ON THE TESTICLES OF MICE.

(E.) Haidt, S. J. (Food Drug Admin., Bur. Radiol. Hlth., Rockville, Md.) and A. H. McTighe. *Proc Int Microwave Symp* (IEEE, New York City, N.Y.) June 1973, p 324-325.

Testicular damage occurred in 7 of 9 inbred mice exposed to 2.45 GHz continuous wave (CW) whole-body radiation at an average exposure of 6.5 mW/cm² for a total of 250 hr over a 2-month period. Rectal temperature remained unchanged following irradiation. Pathological examination showed various stages of tubular degeneration within lesions near the surface of the testicles. Within affected tubules, the cellular layers were disorganized and the normal spermatogenic cycle disrupted. In some cases, vacuole formation occurred and giant cells were present. The interstitium appeared congested and Sertoli cells were prominent. Only 2 of 9 control animals showed similar testicular damage. Considering the spotty distribution of the damage, it is unlikely that infertility would result from chronic, low-level microwave radiation.

0028 CONTINUOUS EXPOSURE OF CHICKS TO ELECTRO-MAGNETIC FIELDS. (E.) Giarola, A. J.

(Texas A. M. U., College Station) and W. F. Krueger. *Proc Int Microwave Symp* (IEEE, New York City, N.Y.) June 1973, p 337-338.

Homogeneity trials indicate that growth depressions previously reported in chicks exposed to a UHF field are from controlled environmental conditions. Power density measurements were obtained in a UHF facility operating at a frequency of 915 MHz. Measurements with an unloaded system yielded a value of approximately 550 µW/cm². Measurements with concentrated and spread loading (day-old-chicks) showed that power density decreases in proportion to loading. With spread loading, the maximum power density at the center of the cage was approximately 250 µW/cm². Water and feeder location may have been responsible for a "hot spot" at the center of the cage at a height of 9.5 cm from the floor. The power density at this point was equal to 900 µW/cm², more than 10 times smaller than the safe level of 10 mW/cm², which is based on thermal effects. It is concluded that the observed growth depressions resulted from "nonthermal" biological responses.

0029 THE EFFECT OF MICROWAVE RADIATION ON EVOKED TACTILE AND AUDITORY CNS RESPONSE IN CATS. (E.) Guy, A. W. (U. Washington Sch.

Med., Seattle), J. C. Lin, and F. A. Harris. *Proc Microwave Power Symp* (Inst. Microwave Power,

Canada) May 1972, p 120-124.

The evoked response of the thalamic somatosensory area and the thalamic auditory relay nuclei of the cat's brain was recorded with and without the presence of 915 MHz microwave radiation. The evoked responses were recorded continuously with micro-waves alternately on and off for 15-min intervals over a total period of 6-12 hr. Stimuli were delivered once per sec. Decreases in amplitude and latency were generally accompanied by an increase in brain temperature caused by irradiation. Mean maximum absorbed power densities at which changes in amplitude and/or latency of tactile and auditory evoked responses were observed within the same range. Average temperature rises associated with these changes were around 1 C. This, together with the similarity of changes in the evoked potentials, strongly suggests that a thermal mechanism is responsible for the change. The mean threshold for latency and amplitude changes was about 5 mW/cm², corresponding to an incident power density of 5.9 mW/cm². To produce the same maximum absorbed power density in the human thalamus would probably require an incident plane wave power density of 10.1 mW/cm².

0030 EFFECT OF AN ULTRAHIGH-FREQUENCY ELECTRO-MAGNETIC FIELD ON PROCESSES OF ENERGY METABOLISM IN ANIMAL TISSUES. (Rus.) Mishchenko,

L. I. (Inst. Ind. Hyg. Occupational Dis., Khar'kov, USSR). *Gig Tr Prof Zabol* 16:48-50, 1972.

The activity of oxidative phosphorylation, measured by the ratio of the decrease in phosphate to oxygen absorption, and the contents of AMP, ADP, and ATP were studied in the brain, heart, and liver of rats exposed to an ultrahigh-frequency (48 MHz) electromagnetic field. Rats were exposed for a total of 15-20 1-hr sessions to (1) an electrical field with an intensity of 800 volts/m or (2) a magnetic field with an intensity of 10 amps/m. Exposure to the ultrahigh-frequency electrical field significantly decreased the activity of oxidative phosphorylation in the heart, but had no appreciable effect on the brain or liver. The ATP content increased in the heart, while ATP and AMP contents tended to increase in the brain. These findings suggest that high-energy phosphate levels in the heart were maintained at an adequate level by an increase in the activity of compensatory mechanisms, primarily glycolytic ones. This is confirmed by the previous finding that the glycogen level decreased while lactate and pyruvate levels increased in the brain and blood of these animals. Changes in the brain can be accounted for by disturbances in the resynthesis of ATP from ADP. Exposure to the ultrahigh-frequency magnetic field increased coupling of oxidative phosphorylation and decreased the activity of oxidative processes in the brain. No appreciable changes occurred in oxidative phosphorylation in the heart or liver. The ATP content of the heart increased significantly and increases also occurred in the content of AMP in the brain (83%) and heart (30%). This might be due to a disturbance in the activity of processes, particularly deamination, in which AMP is broken down and may result

in changes in nitrogen metabolism. (7 references).

- 0031 EVALUATION OF EFFECTS OF THE MICROWAVE OVEN (915 AND 2450 MHz) AND RADAR (2810 AND 3050 MHz) ELECTROMAGNETIC RADIATION ON NON-COMPETITIVE CARDIAC PACEMAKERS. (E.) Bonney, C. H. (Radiobiol. Div., U.S.A.F. Sch. Aerospace Med., Brooks AFB, Tex.), P. L. Rustan, Jr. and G. E. Ford. *IEEE Trans Biomed Eng* BME-20(5):357-364, 1973.

Six cardiac pacemakers were implanted in canines of both sexes in which atrioventricular blocks had been surgically induced. The pacemaker pulse and the resulting ventricular depolarizations were monitored during exposure of the animals to microwave fields at frequencies of 915, 2450, 2810, and 3050 MHz. Aberrations in pacemaker function involved changes in rate (usually bradycardia with two instances of tachycardia) or complete inhibition (cut-off) of the pacemaker. At some modes, the pacemakers exhibited changes in function within a power-density "window"; exposure above or below the "window" produced no effects on pacemaker function. The following field parameters would be regarded as potential situations for complete pacemakers inhibition: 915-MHz-fields continuous- and sine-wave modulation at 120 Hz in field strengths over 75 V/m; and fields at either 2810 or 3050 MHz pulsed at a rate of 40 pulses per second or less with a field strength greater than 250 V/m.

- 0032 SANITARY HYGIENIC STUDIES OF WORKING CONDITIONS DURING HIGH-FREQUENCY HEATING. (Rus.) Nikogosian, S. V. (Erevan Med. Inst., USSR). *Zh Eksp Klin Med* 10(6):108-110, 1970.

Measurements were made of electromagnetic field intensities in working places where a variety of high-frequency generators were employed for heating. The generators produced frequencies ranging from 200-700 KHz and operated at 8-100 Kwatts. Field intensities ranged from 20 to 500 volts/m (for electrical components) and from 0.5 to 90 amps/m (for magnetic components). High field intensities resulted from lack of screening or inadequate screening of radiation sources (condensers, high-frequency transformers, feeder lines, inductors) and observation windows in the generator cabinet. The large differences in field intensities can be accounted for by differences in the designs of the generators. High field intensities were measured when an unscreened high-frequency transformer or condenser was located outside of the generator cabinet. Field intensities reached 350 volts/m and 90 amps/m near unscreened high-frequency transformers and 1600 volts/m and 10 amps/m near unscreened condensers. These values greatly exceed maximum permissible limits established in the Soviet Union (20 volts/m and 5 amps/m). (3 references)

- 0033 EFFECT OF A PULSED ULTRAHIGH FREQUENCY ELECTROMAGNETIC FIELD ON SERUM CHOLESTEROL CONCENTRATIONS IN RABBITS. (Rus.) Todorov, N. (Higher Med. Inst., Sofia, Bulgaria) and V. Draganov.

Patol Fiziol Eksp Ter 17:53-54, 1973.

Serum cholesterol levels were measured in 31 Chinchilla rabbits before and 1, 2, and 3 hr after exposure to ultrahigh frequency pulsed current directed to the brain. A power of 30 watts was employed, and rabbits were exposed for 5 min. Ten nonirradiated rabbits served as controls. In irradiated rabbits the serum cholesterol levels increased from a mean of 94.0 mg/100 ml to a mean of 119.0 mg/100 ml 1 hr after irradiation. Cholesterol concentrations increased further to a mean of 125.0 mg/100 ml after 2 hr and returned to normal after 3 hr. These findings indicate that exposure of rabbits to pulsed short waves "knocks out" cholesterol from the brain and into the blood. (13 references)

- 0034 EFFECT OF ELECTROMAGNETIC FIELDS AND PARAFFIN APPLICATIONS ON PANCREATIC SECRETION. (Rus.) Korepanov, A. M. (No affiliation) and R. V. Bazhenova. *Kazan Med Zh* (6):79-80, 1973.

Spontaneous pancreatic secretion was measured in 161 patients (83 women and 78 men, aged 17-58 yr) before, during, and after application of paraffin or a single 30-min exposure to inductothermy or ultrahigh frequency (UHF) radiation directed over the pancreas. Patients had clinical signs of chronic cholangiohepatitis (118 cases), chronic gastritis with hypochlorhydria (31 cases), and duodenal ulcers (12 cases). Paraffin was applied at temperature of 50-55 C. Inductothermy (13:56 MHz) was given with a small disc inductor operated at 120-180 ma for oligothermal doses and at 250-300 ma for thermal doses. UHF radiation was generated with a UHF-4 apparatus operated at 40 watts for oligothermal doses and at 80 watts for thermal doses. While paraffin applications had no appreciable effect on pancreatic secretion, inductothermy and UHF radiation, administered in oligothermal doses, significantly increased the volume of pancreatic secretion and the carbonate alkalinity. Inductothermy significantly increased trypsin and diastase activities, while UHF radiation significantly increased lipase activity. Thermal doses of inductothermy and UHF radiation suppressed pancreatic secretion and, in the case of inductothermy, increased enzyme secretion. No relationship was found between the results obtained and the nature of the patient's disease. It is recommended that inductothermy and UHF radiation be used in oligothermal doses in the treatment of disorders in which exocrine pancreatic secretion is depressed. These procedures should not be used to treat patients with subclinical or latent pancreatitis, particularly since high-frequency electromagnetic radiation has been found to cause changes in the trypsin inhibitor system in the blood. (No references).

- 0035 HEALTH ASPECTS OF EXPOSURE TO ELECTROMAGNETIC FIELDS IN THE SUPERHIGH FREQUENCY RANGE. (Rus.) Troianskii, M. P. (No affiliation). *Gig Sanit* 37:87-92, 1972.

People may be exposed to high frequency, ultrahigh

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frequency, or superhigh frequency radiowaves from improperly designed generators or from powerful antennae systems. Superhigh frequency (microwave) radiation is the most common type because of the widespread use of this radiation in industry. More than 1000 foreign and Soviet articles have been devoted to the study of its biological effects on the nervous, cardiovascular, and other systems. These effects are cumulative and reversible because of the body's ability to adapt. Animal experiments have demonstrated that adaptation occurs most rapidly in the cerebral hemispheres but occurs much more slowly in other systems, particularly the digestive system. Decimeter waves are the most harmful. In the Soviet Union, the maximum permissible intensities for occupational exposure to the superhigh-frequency range (300-300,000 MHz) are: 10 $\mu\text{watt}/\text{cm}^2$ for the entire work day, 100 $\mu\text{watt}/\text{cm}^2$ for 2 hr exposure or less, and 1000 $\mu\text{watt}/\text{cm}^2$ for 15-20 min/day exposure. The use of protective glasses is required. For subjects who are not occupationally exposed to microwave radiation and for the population surrounding sources of microwave radiation, the intensity of radiation should not exceed 1 $\mu\text{watt}/\text{cm}^2$. (13 references)

0036 COMPARATIVE EVALUATION OF THE HEALTH OF WORKERS EXPOSED TO MICROWAVE RADIATION OF DIFFERENT INTENSITIES. (Rus.) Sadchikova, M. N. (Inst. Ind. Hyg. Occupational Dis., Moscow, USSR) and K. V. Nikonova. *Gig Tr Prof Zabol* 15:10-13, 1971.

Physical examinations were given to (1) 100 workers (83 men and 17 women) who had been exposed to high intensities (up to several milliwatts/cm²) of microwave radiation for 1-10 yr and (2) 115 workers (91 men and 24 women) who had been exposed to less than several hundredths of a milliwatt/cm² for short periods over 1-10 yr. All of these workers were employed in the control, adjustment, and testing of equipment in radar stations; about 3/4 were less than 40 yr old, and about 80% had been employed in these stations for 5-10 yr. These results were compared to those obtained on 100 men who were less than 40 yr old, were employed in similar occupations, but had not been exposed to electromagnetic radiation. Clinical symptoms commonly found in workers exposed to microwaves included heaviness of the head, fatigue, somnolence, irritability, decreased memory, and cardialgia. These symptoms were most common and most pronounced in group (1). Autonomic vascular disorders occurred in both groups (1) and (2), but were more common in group (2). They consisted of dermatographia, hyperhidrosis, labile arterial pressure with a tendency to hypertension, and vascular disorders of the retina. Hypertension was rare in all of the 3 groups examined. ECG tracings revealed that bradycardia and disturbances in intraventricular conduction were significantly more common in groups (1) and (2) than in controls. These findings confirm that exposure to microwaves, even at very low intensities, has a deleterious effect, particularly on the nervous and cardiovascular systems. (12 references)

0037 MICROWAVE THERAPY FOR PATIENTS WITH HYPER-

TENSION. (Rus.) Fastyskovskii, A. D. (Kiev Inst. Postgrad. Med., USSR). *Vopr Kurortol Fizioter Lech Fiz Kult* 37:317-320, 1972.

Microwaves, directed above shoulder level, were used to treat 63 patients with hypertension (stages I and II). Microwaves produced by a centimeter-wave generator and a rectangular emitter of the wave guide type were used at a power density of 0.09-0.18 watts/cm² for 10 min/day for a total of 12-15 sessions. With the exception of 6 patients who had severe hypertension and severe disturbances in cerebral or coronary blood flow and who were given doses of 20-30 watts for the first 3-4 days, all patients received doses of 45-50 watts. After completing the course of microwave therapy, headaches had disappeared in 28 and decreased in severity in 24 of 56 patients; noises in the ears had disappeared in 14 and decreased in intensity in 3 of 25 patients; angina pectoris had disappeared in 15, decreased in severity in 21, and remained unchanged in 4; dyspnea had disappeared in 15 and decreased in severity in 4 of 33 patients; sleep was normalized in 14 and improved in 13 of the 35 patients who had complained of difficulties. Increased pressure in the brachial arteries, which was observed in 58 patients before therapy, had normalized in 13, decreased in 39, and remained unchanged in 5. Asymmetry in arterial pressure disappeared in 15 of 32 patients. Microwave therapy also caused neurological improvement (tendon reflexes, tremors, Romberg's sign, dermatographism, sucking reflex, Marinesco's reflex, etc.). Cardiac rhythm normalized in 17 of 24 patients who had initially had disturbances; signs of intraventricular disorders in conduction decreased in intensity in 27 of 31 patients; improvements occurred in myocardial contractility in 27 of 43 patients; the position of the electrical axis of the heart normalized in 9 of 29 patients; some decrease in enlargement of the left side of the heart occurred in 14 of 17 patients; and signs of chronic coronary insufficiency disappeared in 9 and decreased in severity in 30 of 49 patients. At discharge, 17 patients showed significant improvement, 22 had improved, 19 had improved slightly, and 3 remained unchanged. The best results were obtained on patients with stage I hypertension. (No references).

0038 CHANGES IN ELECTROGASTROGRAPHIC PARAMETERS IN PATIENTS WITH PEPTIC ULCERS AFTER COMBINED THERAPY IN WHICH MICROWAVE RADIATION WAS USED. (Rus.) Chistiakova, N. S. (Central Clin. Hosp., 4th Chief Administrative Office, Ministry Hlth., Moscow, USSR), L. A. Skurikhina, Z. K. Mamaeva and A. D. Arapova. *Vopr Kurortol Fizioter Lech Fiz Kult* 37:341-344, 1972.

Electrogastrograms (EGG) were traced before and after treatment in 40 patients and after simulated exposure to microwaves in 12 patients with gastric and duodenal ulcers. Most of these patients were men, aged 25-60 yr, who had exacerbations (37 cases) of acute, recurrent, or chronic peptic ulcers. Microwave therapy (no further details) and drugs (unspecified) were administered to 30 patients, while 10 received drugs alone. EGG changes were observed in 25 patients before treatment. They consisted of increases in amplitude in 18 and decreases in am-

plitude in 7. More than one-third of the tracings contained irregularities, arrhythmic variations, and pathologically deformed spikes. Increased electrical activity was observed in 12 of the 18 patients with recurrent duodenal ulcers, while decreases occurred primarily in patients with recurrent and chronic gastric and duodenal ulcers. After combined microwave and drug therapy, electrical activity had normalized in 14 and improved in 4 of the 19 patients who initially showed abnormalities; the rhythm also normalized in one-half of the patients in this group. Ulcer healing had occurred in all 14 patients in whom electrical activity normalized and in 3 of the 4 patients with improved EGG tracings. After drug treatment alone, EGG tracings normalized in only 1 and improved in 4 of 10 patients; small changes occurred in the biopotential and mean amplitude, and no appreciable change occurred in the rhythm. No changes in EGG biopotentials occurred in the patients subjected to "sham" microwave therapy. Two illustrative case reports are presented. (6 references)

0039 EFFECT OF ANTIOXIDANTS ON PROTEIN METABOLISM AFTER MICROWAVE IRRADIATION. (Rus.)

Koldaev, V. M. (I. P. Pavlov Med. Inst., Ryazan, USSR). *Vopr Kurortol Fizioter Lech Fiz Kult* 36:246-248, 1971.

To determine the effects of antioxidants on the concentrations of serum proteins and labile globulins after microwave irradiation, cystamine dihydrochloride (130 mg/kg i.p.) was injected in noninbred male albino rats 10 min before they were exposed to a single dose of microwave radiation (power density of 140-160 milliwatts/cm² for 12 or 24 min). Cystamine alone had no appreciable effect on serum protein concentrations, and radiation alone produced relatively minor changes in the concentrations of serum albumins and β -globulins. When cystamine was injected before 12-min exposure to microwave radiation, significant decreases were observed in the concentrations of serum albumins and α_1 -globulins, while serum β - and γ -globulins were increased 3 min after radiation. Although serum albumin and α_2 -globulin concentrations had almost normalized 24 hr after irradiation, the concentrations of other serum protein fractions still differed appreciably from control values. Similar results were obtained when rats were irradiated for 24 min. While cystamine alone had little effect on concentrations of labile globulins (primarily the β - and γ -globulin fractions) in the serum, 12-min exposure to microwaves increased labile globulin concentrations 1.35-fold 3 min after irradiation. Labile globulin concentrations increased 2-fold 3 min after irradiation and were still increased 1.6-fold 24 hr after irradiation when cystamine was injected before exposure to microwaves. Similar results were obtained when rats were exposed to microwaves for 24 min. These results indicate that greater changes occur in protein metabolism when cystamine is injected before irradiation than with irradiation alone. (4 references).

0040 MICROWAVE THERAPY IN THE COMBINED TREATMENT OF PATIENTS WITH ACUTE PNEUMONIA.

(Rus.) Nesmenianova, E. I. (Munic. Clin. Hosp.,

Vladivostok, USSR). *Vopr Kurortol Fizioter Lech Fiz Kult* 37:345-347, 1972.

Microwave therapy, combined with other forms of treatment (sulfonamides, antibiotics, cardiovascular agents, and vitamins), was administered to 79 patients (62 men and 17 women, aged 17-70 yr) with pneumonia. Complications were present in 8 cases: toxic hepatitis in 3 and intralobular pleuritis in 5. Associated diseases included coronary and cerebral atherosclerosis, chronic coronary insufficiency (stage I), hypertension combined with atherosclerosis, duodenal ulcers, periduodenitis, postgastrectomy syndrome and others. A control group of 30 pneumonia patients received the same treatment with the exception of microwave therapy. The microwave emitter, 14 cm in diameter, was placed 5-7 cm away from the chest. Patients were exposed for 15-20 min/day for 10-14 days using a flux of 50-60 watts. After irradiation the skin temperature had increased by 1-4 C. Symptomatic improvement, which occurred more rapidly than in the control group, was evident in most patients after 3-7 sessions of microwave therapy. After the course of therapy had been completed, radiological signs of pneumonia had disappeared in 56 of the 79 patients. Residual changes were observed in 23 patients including 3 chronic alcoholics, 4 who had been hospitalized late in the disease, and 7 with croupous pneumonia which developed against a background of chronic pneumonia. In the control group, radiological signs of pneumonia disappeared only after 15-17 days, even in those who had no complications. After completion of microwave therapy the minute respiratory volume, vital capacity, and maximum pulmonary ventilation had normalized 68-87% of the 69 patients in whom these values were measured. No deleterious changes occurred in the cardiovascular system, and improvement in the ECG occurred in 6 of 13 patients with signs of myocardial hypoxia. (3 references)

0041 THE ACTION MECHANISM OF MICROWAVE THERAPY IN OPHTHALMOLOGIC PRACTICE. (Rus.)

Grechushkina, V. A. (Helmholtz Inst. Eye Dis., Moscow, USSR). *Vopr Kurortol Fizioter Lech Fiz Kult* 37:337-341, 1972.

Small doses of microwaves were used to treat 19 patients with acute disturbances in retinal circulation and 51 patients with macular degeneration classified as senile degeneration (19 cases), congenital degeneration (5), central myopic chorioretinal degeneration (17), trauma (5), and degeneration due to other causes (5). Patients were exposed to microwaves for 15 min/day or on alternate days (up to 20 sessions) with doses which produced increases of 0.5-0.6 C in the eyes of rabbits but were unlikely to increase temperatures within the less sensitive human eye. In patients with disturbances in retinal circulation the rate at which bleeding and plasmoregic were resolved and with which retinal edema disappeared were increased by microwave therapy. Visual acuity improved in 18 of the 19 patients. The best results were obtained in patients with vascular spasms and thrombosis of the central artery of the retina and its branches followed by patients with thrombosis in branches of the central vein of

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the retina. Scotoma completely disappeared in seven patients and absolute scotoma became relative in five. Microwave therapy produced improvements in visual acuity in 49 of the 51 patients with macular degeneration; improvements in the nonirradiated eye occurred in 32 of the 41 patients with bilateral degeneration. Microwave therapy was most effective in patients with recent degeneration, and the best results were obtained on patients with recent traumatic bleeding in the macular region; no effect was observed in patients with macular fibrosis resulting from past bleeding. Absolute scotoma disappeared completely in 20 patients, became relative in 10, and was definitely less pronounced in 33. Bleeding was completely resorbed in 18 of 26 patients and was considerably reduced in its extent in five; two patients developed some greenish pigmentation. From measurements made on 56 patients from both groups it was shown that microwave therapy reduced arterial pressure by 5-10 mm Hg in normotensive patients and by 10-15 mm Hg in hypertensive patients. Increased intraocular pressure, which was detected in several patients before therapy, generally decreased by 3-4 mm Hg to normal values. In nine of the ten patients examined by rheoophthalmologic methods it was found that microwave therapy increased the volume pulse by an average of 50%, while only a 24% increase was observed in the nonirradiated eye. The index for the elasticity of the vascular walls increased by an average of 41% in the irradiated eye and only by 27% in the nonirradiated eye. Photocalibrometry, used to examine four patients from both groups revealed that arteries in the irradiated eye were dilated by 8-25 μ . This dilatation reached a maximum 40-60 min after irradiation. These findings suggest that microwaves have a vasodilating action which improves retinal circulation and the blood supply of the retina.

- 0042 SIGNIFICANCE OF MICROTHERMAL EFFECTS DERIVED FROM LOW LEVEL UHF-MICROWAVE IRRADIATION OF THE HEAD: INDIRECT CALORIC VESTIBULAR STIMULATION. (E.) Lebovitz, R. M. (U. Texas Southwestern Med. Sch., Dallas). *J Theor Biol* 41:209-221, 1973.

Analysis of the effects of incident low level UHF microwave irradiation of the head suggests that biochemically significant microthermal effects are unlikely. However, small local thermal effects could be neurophysiologically significant. It is hypothesized that low level microwave radiation can lead to indirect input to the CNS via anomalous activity of sensory specializations in the vestibulo-cochlear apparatus. It is estimated that microwave irradiation at incident power densities of about 40 mW/cm² can be detected by humans via the vestibular coupling effect. If this is true, personnel who work with microwave equipment might be able to use this vestibular sensation as an early warning of possibly harmful exposure. This vestibular effect could probably mediate a variety of cardiorespiratory reflexes and evoked potentials in portions of the nervous system. It would offer an alternate explanation for many effects which are called "nonthermal or direct" effects of microwaves. In small animals microwaves might produce an intralabyrinthine resonance effect

which would significantly increase the magnitude of the induced vestibular stimulus. (21 references)

- 0043 POSSIBLE MECHANISMS FOR THE BIOMOLECULAR ABSORPTION OF MICROWAVE RADIATION WITH FUNCTIONAL IMPLICATIONS. (E.) Rabinowitz, J. R. (New York U. Med. Ctr., New York, N.Y.). *Proc Int Microwave Symp* (IEEE, New York City, N.Y.) June 1973, p 314-315.

Theoretical analysis of the possible modes of molecular interaction with microwave radiation suggests that absorption of a microwave photon may interfere with stereospecific biomolecular processes. The absorption of the photon by a molecular segment would increase its rotational energy. As a result, the segment might be a state that is localized in more than one potential well, like states C and D, and re-emission of the photon may result in its rotation being localized in a well different from the initial well. Or the segment may be excited to a state like B, still confined to the same potential well but with enough energy to greatly increase the possibility of tunneling to another wall. Both of these effects lead to the same type of structural changes: covalent molecular structure remains unchanged but the relative position of one segment of the molecule with respect to the remainder of the molecule is altered. The effect of microwave radiation on stereospecific biomolecular processes would probably be frequency dependent, and if allowed a long enough time, reversible.

- 0044 A NONPERTUBING TEMPERATURE SENSOR FOR MEASUREMENTS IN ELECTROMAGNETIC FIELDS. (E.) Rozzell, J. T. (Office Naval Res., Arlington, Va.), C. C. Johnson, C. H. Durney, J. L. Lord, and R. G. Olsen. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) Sept. 1973, p 2B4/1-2B4/2.

An electro-optical temperature measuring device which neither perturbs electromagnetic fields nor causes hot spots has been developed for use in monitoring temperature in biological systems during electromagnetic radiation. The probe is constructed entirely of dielectric material. A plastic sheath enclosed two fiberoptic bundles which transmit to and receive light from the top. A dielectric colorimetric temperature-sensitive tip alters the light reflected in the receiving fiberoptic bundle and provides a light level proportional to tip temperature. A pulsed gallium arsenide phosphide light-emitting diode (LED) is closely coupled to the proximal tip of the transmitting fiberoptic bundle. A silicon photodiode is coupled to the receiving fiberoptic bundle and generates a voltage proportional to reflected light level. The LED is pulsed at 200 Hz with a 10 microsec pulse length. A sample/hold circuit receives the reflected pulse height and generates a d.c. voltage which is detected and amplified.

- 0045 EFFECTS OF MODULATED VERY HIGH FREQUENCY FIELDS ON SPECIFIC BRAIN RHYTHMS IN CATS. (E.) Bawin, S. M. (Dept. Anat., U. California,

Los Angeles), R. J. Gavalas-Medici and W. R. Adey.
Brain Res 58:365-384, 1973.

The effects of exposures to low intensity (1 mW cm² or less), very high frequency (VHF) (147 MHz) electrical fields, amplitude-modulated at biological frequencies (1-25 Hz), were studied on untrained and conditioned chronically implanted cats. The fields were applied between two aluminum plates (identical voltages, 180° phase shift) firmly anchored to the floor of an isolation booth, especially designed for use with VHF fields. The animals were restrained in a hammock, the longitudinal axis of the body being kept parallel to the field plates. EEG and EOG were recorded through a system of low pass filters on a Model 6 Grass electroencephalograph and an Ampex FR 1100 tape recorder; behavior was continuously observed through a closed circuit TV. A series of animals was operantly trained to produce specific transient brain rhythms following periodic (every 30 sec) presentations of a light flash stimulus. The levels of performance were established (visual and spectral analysis) during conditioning and extinction schedules for a series of cats submitted to VHF fields amplitude-modulated at the dominant frequencies of the selected transient patterns and for a control group in the absence of fields. The irradiated animals differed markedly from the control group in the rate of performance, accuracy (in terms of frequency bandwidth) of the reinforced patterns and resistance to extinction (minimum of 50 days versus 10 days). The specificity of the frequency of the modulation was tested on another group of untrained animals where spontaneous transient patterns were used to trigger for short epochs (20 sec following every burst) the VHF fields amplitude-modulated at various frequencies. The experimental results indicated clearly that the fields were acting as reinforcers (increasing the rate of occurrence of the spontaneous rhythms) only when modulated at frequencies close to the biologically dominant frequency of the selected intrinsic EEG rhythmic episodes.

0046 EFFECT OF VERY HIGH FREQUENCY (RADAR) ELECTROMAGNETIC RADIATION ON THE CENTRAL NERVOUS SYSTEM IN THE ALBINO RAT. ELECTROCORTICOGRAPHIC CHANGES. (Fr.) Bertharion, G. (St. Anne HIA, Toulon, France), B. Servantie and R. Joly. *C R Soc Biol (Marseille)* 165(9/10):1928-1930, 1971.

Profound changes were found in electrocorticographic tracings made on age- and weight-matched Charles River France rats exposed to very high frequency (VHF) radiation with a power flux density of 5 ± 2 mW/cm² for 7 days, 1 month or 5 months. Many paroxysmal bursts, consisting of the appearance of points and even point-wave complexes were found, particularly in the occipital lead. A pointed θ rhythm with some isolated slow waves appeared in the occipital lead; this may be a manifestation of brain damage. Paroxysmal bursts began to appear in both the frontal and occipital leads after 48 hr exposure to VHF radiation. Within 48-72 hr after the rats had been removed from the source of radiation, electrocorticographic tracings returned to normal in all irradiated animals. It is hypothesized that VHF ra-

diation acts on the cortex, either directly or indirectly, by reticular stimulation. Exposure to VHF radiation may trigger an ascending activator system in the reticular formation which predominates over the descending inhibitor system. (No references)

0047 EFFECT OF HIGH-FREQUENCY ELECTROMAGNETIC FIELD UPON HAEMOPOIETIC STEM CELLS IN MICE. (⁵⁹Fe INCORPORATION/SPLEEN CELLS/BONE MARROW/SPLEEN-COLONY ASSAYS). (E.) Rotkowska, D. (Inst. Biophysics, Czechoslovak Acad. Sci., Brno) and A. Vacek. *Folia Biol (Praha)* 18(4):292-297, 1972.

The effect of a single, whole-body exposure to high frequency (2450 MHz) electromagnetic radiation (HFR) (intensity 100 mW/cm², wave length about 12.5 cm) for 5 min on spleen and bone marrow ⁵⁹Fe incorporation and endogenous and exogenous spleen colony assays was investigated in intact, adrenalectomized, and sham-operated 7-week-old female C57Bl mice. Exogenous spleen colony assays were performed 10 days after exposure to 700 r of x-rays followed, 2 hr later, by injection of donor spleen cells. Endogenous spleen colony counts were made in mice 10 days after exposure to x-rays preceded 14, 3, 2, and 1 day and 5 min by exposure to HFR. HFR caused a transient increase in ⁵⁹Fe incorporation by the bone marrow and spleen and in the number of exogenous spleen colonies. This increase was followed, 24 hr later, by a decrease and then a gradual increase. After 14 days ⁵⁹Fe incorporation in the spleen was significantly greater than in controls, but bone marrow values did not differ appreciably from control values. The number of exogenous spleen colonies was significantly higher in irradiated mice than in controls 48 and 72 hr after exposure. Statistically significant increases in the number of endogenous spleen colonies were observed only 14 days after exposure to HFR. No differences were found in the patterns of ⁵⁹Fe uptake by the spleen in intact, sham-operated, and adrenalectomized mice. Exposure to HFR protected mice against exposure to sublethal doses of x-rays (600 r). While only 14% of the controls survived for 30 days, exposure to HFR increased 30-day survival to 53%, 88%, and 90%, resp. when given 24 hr, 3 days, and 14 days, resp. before x-irradiation. These findings suggest that increased ⁵⁹Fe incorporation and the number of exogenous and endogenous spleen colonies are probably a reflection of intense regeneration of hematopoietic tissue caused by a loss of stem cells resulting from exposure to HFR. The adrenal gland is not directly involved in the action mechanism of early hemopoietic changes. (16 references)

0048 EFFECT OF A LOW-FREQUENCY IMPULSE MAGNETIC FIELD ON THE ACTIVITY OF OXIDATION-REDUCTION ENZYMES IN ALBINO RAT LIVER. (HISTOCHEMICAL STUDY). (Rus.) Iashina, L. N. (Inst. Industrial Hyg. Occupational Dis., Khar'kov, USSR). *Gig Tr Prof Zabol* 16:53-56, 1972.

Adult male Wistar rats were exposed to an impulse magnetic field with an intensity of 24 or 72 ka/m (300 or 900 oersteds, resp.), a frequency of 7 KHz, an impulse duration of 130 microsec, and an inter-

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val between impulsed of 10 sec. The first group of rats was exposed to 72 ka/m (900 oersteds) for 3 hr/day (15 sessions) and the second group to 24 ka/m (300 oersteds) for 1.5 hr/day for 1, 3, and 6 months. Histochemical examinations of the livers of these animals after exposure to the impulse magnetic field showed a marked decrease in the activities of succinate, isocitrate, and malate dehydrogenases in animals belonging to the first group. A decrease was also noted in the activity of glutamate dehydrogenase, an enzyme which takes part in the synthesis of various amino acids and in the reaction in which NH_4^+ is bound to ketoacids in detoxification. In the second group of rats similar changes occurred in the activities of these enzymes along with necrobiosis and damage to the mitochondrial membrane. Decreases in succinate dehydrogenase activity persisted in some cells even 2 months after exposure to radiation had been discontinued. (9 references)

0049 CHANGES IN THE CARDIOVASCULAR SYSTEM DUE TO CHRONIC EXPOSURE TO AN ULTRAHIGH FREQUENCY FIELD. (Rus.) Muratov, V. I. (No affiliation) and A. P. Turaeva. *Voen Med Zh* (1):22-24, 1972.

Cardiovascular examinations were performed before and after measured physical exercise on 25 men, aged 21-39 yr, who had serviced a superhigh frequency (SHF) generator for 2-17 yr. This generator produced waves in the centimeter range with frequencies of 3000-30,000 MHz and power flux densities of 40-310 $\mu\text{watts}/\text{cm}^2$. The exposure time for these subjects averaged 3.5 hr/day. On the basis of the results obtained, subjects were classified into three categories. All findings were within normal limits, both before and after exercise, in 11 subjects. The second group consisted of seven subjects with a tendency toward hypertension. Consistent increases in the mean hemodynamic pressure were noted at rest and after exercise. The diastolic pressure was within normal limits, but the systolic pressure ranged from 132 to 150 mm Hg; no significant changes occurred after exercise. The minute volume was increased and the peripheral resistance decreased in all of these subjects. Mild hypodynamia at rest was observed in the systolic phase. This was manifested in a lengthening of the stress phase, a decrease in the intra-systolic index, and an increase in the myocardial stress index. These parameters improved after exercise. The rate at which pulse waves were propagated at rest was within normal limits, but the ratio of pulse wave propagation through vessels of the muscular type to the rate through the elastic type (S_M/S_E) increased after exercise. The third group consisted of seven normotensive subjects whose hemodynamic parameters improved after exercise. No relationship was found between the duration of exposure to SHF radiation and changes in the hemodynamic parameters. No significant changes in the ECG were found in any of the subjects. Cardiovascular changes observed in some subjects chronically exposed to UHF radiation are considered to be a form of neurovegetative dystonia. Since no relationship was found between the duration of exposure and changes in hemodynamic parameters, other factors may play a role in the development of disorders in neuro-

humoral regulatory mechanisms in workers exposed to SHF radiation. (9 references)

0050 EXPERIENCE WITH MICROWAVE TREATMENT OF DISEASES OF THE ORGANS OF LOCOMOTION.

(Rus.) Getman, E. G. (1st Munic. Hosp., Nikopol', USSR). *Klin Khir* (8):82-84, 1972.

Outpatient microwave therapy was used to treat 193 patients (58 men and 135 women) with acute (9 cases), subacute (70), and chronic (114) diseases of the joints and muscles. These consisted of 52 with dystrophic arthritis, 51 with scapulohumeral peri-arthritis, 34 with calcaneal bursitis, 23 with humeral epicondylitis, 13 with peri-arthritis of the knee joint, eight with traumatic arthritis, and 12 with myositis. Power outputs ranged from 6-15 watts, and exposure times from 8 to 12 min/day; in most cases the time was increased by 2 min after four to six sessions. The number of sessions varied from six to fifteen. Microwave therapy was combined with therapeutic gymnastics in 18 cases and with massage in 14. In 12 cases microwave therapy was administered alternately (every other day) with other physical methods (paraffin applications, ultrasound, etc.). Drug therapy and bandaging to immobilize the joints were employed on patients with acute forms, and some patients received nerve blocks with procaine and hydrocortisone. Microwave therapy had a beneficial effect in 165 cases (85.5%) and had no effect in 28 (14.5%). The best results were obtained with 87 patients who received 12-15 sessions of microwave therapy: a beneficial effect was observed in 92% while 8% showed no improvement. Follow-up examinations, performed on 141 patients, revealed that 54 had recovered completely, for all practical purposes, 1-3 weeks after therapy was discontinued. (No references)

0051 EFFECT OF A SUPERHIGH FREQUENCY FIELD ON THE PHYSICAL TRAINABILITY OF EXPERIMENTAL ANIMALS. (Rus.) Gusarov, D. V. (No affiliation). *Voen Med Zh* (3):61-66, 1971.

Male albino mice, with 1.5 g weights attached to the base of their tails, were exposed to microwave radiation in plexiglas cages which were rotated 36° every 10 min to insure uniform irradiation. After the mice had been trained to swim, exposure to microwaves (wave length 12.6 cm, power flux density 10 mW/cm^2 for 2 hr every other day) significantly reduced their swimming times until after 15 sessions, irradiated mice were only swimming for half as long as nonirradiated controls. This effect was even more pronounced if mice were exposed to the same dose of radiation before they were trained to swim: the swimming time of untrained irradiated mice decreased progressively with time until they were swimming only one-fifth as long as nonirradiated controls after 14 training sessions. In more highly trained mice microwave exposure had less effect. The unfavorable effect of microwave irradiation on training also depended upon the intensity and dose of radiation, the presence of other unfavorable factors, and the time which had elapsed since the last exposure to microwaves. While irradiation with a power flux density of 1 mW/cm^2 had no effect on the next day's

swimming, use of a power flux density of 10 mW/cm² reduced the swimming time for the next six training sessions. If trained mice were forced to swim in water colder than usual, no difference was found between the swimming times of mice irradiated once and nonirradiated controls. However, if mice were exposed to ten sessions of radiation, there was a significant decrease in the swimming time of irradiated mice. Although the swimming times of nonirradiated controls returned to their original level during the next training session, those of mice irradiated with 1 and 10 mW/cm² did not return to initial values until the fourth and seventh sessions, resp. after the test with cold water. These findings suggest that microwave exposure makes it more difficult for the mice to select the optimal variant of motor activity. (7 references)

0052 EFFECT OF MICROWAVES ON THE REACTIONS OF
THE WHITE BLOOD CELLS SYSTEM. (E.)

Baranski, S. (Inst. Biostructure, Med. Acad., Warsaw, Poland). *Acta Physiol Pol* 23(4):685-695, 1972.

Guinea pigs were irradiated for 3 hr daily over a period of 3 months with microwaves of pulse modulation or constant modulation at a power density of 3.5 mW/cm². Their peripheral blood, bone marrow, lymph node, and spleen cells were then examined in terms of mitotic index, maturation curves, and incorporation of ³H-thymidine. No changes in the granulocytic blood system were found in the irradiated animals. However, the cells in the lymphocytic system showed mitotic disturbances (an increase in the mitotic index), increased ³H-thymidine incorporation, and nuclear structure changes. These changes indicated a stimulation of lymphopoiesis. The changes in the peripheral blood correlated with changes in the structure of the spleen and lymph nodes.

0053 MICROWAVE OVENS AND THEIR PUBLIC HEALTH
SIGNIFICANCE. (E.) Elder, R. L. (Public
Health Service, Bureau Radiol. Health, Rockville,
Md.) and W. E. Gundaker. *J Milk Food Technol* 34(9):
444-446, 1971.

There are currently 90 to 130 thousand microwave ovens being used in homes and commercial establishments and the number of units sold in the United States is expected to increase greatly in the next 2 to 3 years. Microwave ovens may have detrimental thermal and nonthermal (field) effects on living organisms. According to the Department of Health, Education, and Welfare performance standard, units manufactured after October 6, 1971 leakage will be limited to 5 mW/cm² throughout the life of the oven. Recent field surveys have found that approximately 20 to 33% of all microwave ovens surveyed emit microwave leakage in excess of 10 mW/cm². Proper maintenance on the part of the owner and improved servicing, including a microwave emission measurement, seem to be significant factors in maintaining control over excessive leakage. In particular, since any object which accumulates on the door seal of the oven can allow leakage to increase, basic sanitation is vital to microwave oven

safety. Other problems which will indicate the potential for unnecessary leakage include a loose door (indicating excessive hinge wear), an interlocking door, and a malfunctioning cooking indication light. State and local health workers are urged to take an active part in convincing owners to implement proper maintenance procedures and to practice good sanitation.

0054 COMPARATIVE ASPECTS OF RADIOFREQUENCY AND
MICROWAVE BIOMEDICAL RESEARCH. (E.)

Michaelson, S. M. (Sch. Med. Dent., U. Rochester, N.Y.) and H. P. Schwan. *Proc Int Microwave Symp* (IEEE, New York City, N.Y.) June 1973, p 330-332.

Physical "scaling" and comparative biomedical aspects of size, metabolism, and thermal tolerance are discussed as criteria for selecting experimental animals to assess biologic effects and potential hazards to man from exposure to microwaves. From a spectrum of species, basic information on the comparative reaction of biologic systems can be acquired which in turn can be used to elucidate mechanisms of action. For the study of physiologic function, a common parameter such as metabolic rate, body weight, or body surface could be utilized to provide an index of extrapolation among species. A combination of biomedical parameters should permit assessment of changes in basic physiological functions, differentiation of normal and pathophysiological states, differentiation of specific and non-specific reactions, and differentiation of defensive-adaptational or compensatory changes, which show self-regulatory properties, from pathological manifestations.

0055 AN RF DECOUPLED ELECTRODE FOR MEASUREMENT
OF BRAIN TEMPERATURE DURING MICROWAVE
EXPOSURE. (E.) Larsen, L. E. (Walter

Reed Army Inst. Res., Washington, D.C.), R. A. Moore, and J. Acevedo. *Proc Int Microwave Symp* (IEEE, New York City, N.Y.) June 1973, p 262-264.

A thermistor probe mount combining microcircuitry, current limiting, series resistance, and thermal isolation enables measurement of temperature to a resolution of 0.1 C in the anterior hypothalamic/preoptic area of the brain of subject animals in the presence of continuous RF radiation. The mount and all its connections did not alter absorption in a 3 cm hemisphere filled with dielectric approximating brain at 918 and 2450 MHz. Comparative thermograms for other temperature probes showed an altered pattern of power absorption.

0056 PERTURBATIONS OF THE MICROWAVE FIELD BY
EXPERIMENTAL ANIMAL AND APPARATUS IN
BIOLOGICAL RESEARCH. (E.) Carpenter, R. L. (North-
eastern Radiol. Hlth. Lab., Winchester, Mass.),
E. S. Ferri, and G. J. Hagan. *Proc Microwave Power
Symp* (Inst. Microwave Power, Canada) May 1972, p 196-
197.

Availability of reliable radiation survey meters has simplified measurement of power density at given points in the near- or far-fields. However, field perturba-

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tion by the test animal or ancillary equipment, even if made of material with a low dielectric constant, is a problem in biological research on microwave effects. The effect of Plexiglas (dielectric constant 2.7-3.2 at 10^6 Hz) on the radiation field was tested in the far zone in an anechoic chamber. Radiation source was a Raytheon Model PGM-100 generator (2.45 GHz frequency, 800 watts maximal output). Depending on their placement, perturbation by Plexiglas sheets greatly increased or decreased the initial free field power density of 100 mW/cm². The greater their thickness, the more pronounced was the effect. Power density was 152 mW/cm² when a single 1/4 in. sheet was placed 1/4 wavelength from the probe compared with 24 mW/cm² when the distance was 1 wavelength. The highest reading (192 mW/cm²) resulted with two sheets, one on each side of the probe, at the 1/4 wavelength distance. With each sheet at the 1 wavelength distance, the reading was the lowest (16 mW/cm²). Uniform power contours were plotted for the radiation field before and after insertion of animals, Plexiglas cylinders, or irregular forms. The resulting perturbations were extensive, complex, and unpredictable.

0057 ACCURATE MEASUREMENT OF MICROWAVE FIELDS FOR MEDICAL AND BIOLOGICAL APPLICATIONS.

(E.) Toler, J. C. (Georgia Inst. Technol., Atlanta). *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) Sept. 1972, p 2B3/1-2B3/2.

Microwave fields are used increasingly in medical and biological research. Yet measurement of these fields in shielded enclosures or anechoic chambers often results in unreliable, nonrepeatable, and inaccurate data. In the case of shielded enclosures, data errors can be attributed to standing waves generated by multipath propagation due to reflections from the enclosure walls, floor, and ceiling. A hooded antenna technique has proved highly successful in alleviating these problems. In the case of anechoic chambers, materials and devices commonly used in the test configuration (e.g. Plexiglas containers, interconnecting wires, instrumentation etc.) are readily capable of perturbing the exposure environment and causing erroneous data. An optical measurement technique that has reduced error to acceptable levels is presented.

0058 THE BIOLOGICAL EFFECTS OF ELECTROMAGNETIC WAVES AND THEIR RELATIONSHIP TO PENDING CANADIAN REGULATIONS. (E.) Ghosh, S. K. (Radiat.

Prot. Div., Dept. Natl. Hlth. Welfare, Ottawa, Canada) and A. M. Muc. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) May 1972, p 25-28.

Growing public concern over the increasing number and power of sources of electromagnetic radiation has been reflected in legislation in several countries. In Canada, the Radiation Emitting Devices Act was enacted in May 1970. Radiation leakage limits relevant to specific classes of devices are set in regulations under the provisions of this Act. Microwave ovens, whether domestic, commercial, or industrial, must be designed so that the leakage level at a distance of 5 cm from any point on the external

level is less than 1.0 mW/cm². Other regulations now under study will deal with microwave blood warmers and diathermy units. That biological systems and materials respond to electromagnetic radiation exposure is well established, but many published studies given insufficient information on the essential parameters of exposure conditions and radiation characteristics. The conflicting and often imprecise data renders the job of specifying regulatory standards extremely difficult.

0059 INSECT-CONTROL POSSIBILITIES OF ELECTROMAGNETIC ENERGY. (E.) Nelson, S. O.

(U.S. Dept. Agriculture, Agricultural Res. Service, Lincoln, Neb.). *Cereal Sci Today* 17(12):377-378, 387, 1972.

Three regions of the electromagnetic spectrum (the infrared-, gamma-, and radiofrequency (RF)-radiation regions) have been identified as offering potential means for controlling insect species of concern in the baking and milling industries. Numerous insect control studies have been conducted in the RF dielectric-heating range, and some studies have been conducted at microwave frequencies. Materials such as grain can be exposed to high-frequency electric fields between electrodes coupled to RF electronic power oscillators; at microwave frequencies, such materials are exposed to the energy in microwave oven enclosures or waveguide applicators. Stored-grain insects can be controlled by exposures which do not damage grain, but only at costs several times higher than those of chemical control methods. The insects can be heated selectively if their dielectric properties bear the proper relationship to those of the grain. A high insect-to-grain dielectric-loss-factor ratio is desired, with an insect-to-grain dielectric-constant ratio also being preferable. The most efficient insect control can probably be achieved in the frequency range between 10 and 100 MHz. Some evidence indicates that factors other than heating may be involved in the effects of RF fields on biological materials, suggesting possibilities for the development of more efficient RF insect-control methods.

0060 MICROWAVE DOSIMETRY. (E.) Vetter, R. J.

(Bionucleonics Dept., Purdue U., West Lafayette, Ind.), P. L. Ziemer and D. Puntenney. *Res/Dev* 24(4):22-26, 1974.

The biological effects of microwaves are largely due to heating or hypothermia, although there is some evidence that nonthermal effects of a neurological and psychological nature may be produced by relatively low level radiation. Specific organs such as the eyes and testes are particularly susceptible to the effects of microwaves. At the present time, there is no microwave field measuring device that is small enough to be placed *in toto* in a free field without causing significant perturbation of the field. Nor is there a small device which integrates the microwave energy incident upon a test object or animal. A new dosimeter is described which is designed to integrate the energy density during

microwave irradiation and to monitor the microwave exposure of personnel working around microwave producing equipment. The dosimeter is small, relatively inexpensive, and passive (i.e., powered by the microwave field); it integrates the microwave energy through the use of a coulometer. The dosimeter could be used for several frequencies and, in practice, will integrate power density over time yielding energy density.

0061 DETERMINATION OF THE PROPERTIES OF THE BOUND WATER IN BIOLOGICAL SAMPLES BY MICROWAVE METHODS. (E.) Almasy, G. (TKI, Budapest, Hungary) and M. B. S. Misik. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) Sept. 1973, p 1B3/1-1B3/2.

Microwave measurements give direct information about the structure of "bound" water of the living cell. For the measurement of the microwave dielectric parameters of biological samples, cavity resonator techniques are suitable. Dielectric parameters are deduced from measurements of resonant frequency and Q-factor of the cavity resonator. Measurements performed on frog nerves show that interaction between albumens and water has a considerable bearing on dielectric parameters. The dielectric decrements depend to a great extent on temperature.

0062 BRADYCARDIA IN ISOLATED HEARTS INDUCED BY MICROWAVE IRRADIATION. (E.) Lords, J. L. (U. Utah, Salt Lake City), C. H. Durney, A. Borg, and C. Tinney. *Proc Int Microwave Symp* (IEEE, New York City, N.Y.) June 1973, p 335-336.

Continuous 960 MHz irradiation (estimated 5 mW absorbed) of isolated poikilothermic hearts in Ringer's solution caused bradycardia, in contrast to the tachycardia usually produced by generalized heating. The effect occurred only over the range 100-200 mW total power. The bradycardia suggests that specific heating took place at one of several tissue interfaces within the heart, particularly at the myelin-muscle interface involving the remnants of the cut nerves enervating the myocardium. The interface responded by initiating firing in the nerves of the parasympathetic system, the result being a decrease in heart rate.

0063 THE PACEMAKER PATIENT AND THE ELECTROMAGNETIC ENVIRONMENT. (E.) Smyth, N. P. D. (George Washington U. Sch. Med., Washington, D.C.), V. Parsonnet, D. J. W. Escher and S. Furman. *J Am Med Assoc* 227(12):1412, 1974.

To cope with the ability of the inhibitory-demand pacemaker to sense electromagnetic interference (EMI) other than the intrinsic myocardial potentials, manufacturers have made improvements in the shielding, filtration, and discrimination of the circuitry of the units. However, as protection against EMI increased, so did the strength and variety of the EMI sources (e.g., leaky microwave ovens). Despite these EMI sources, there are very few documented

cases of EMI affecting implanted pacemakers. The action of environmental EMI on the patient with an implanted demand pacemaker does not at this time constitute an important clinical problem. While the pacemaker manufacturer must continue to improve his product's resistance to EMI, the product must not lose clinically important sensitivity and versatility. Government agencies can control EMI emissions where feasible (e.g. microwave ovens) and impose geographic limitations where this is not feasible (e.g., powerful sources of radar).

0064 MICROWAVE OVEN INTERFERENCE WITH CARDIAC PACEMAKERS. (E.) Rustan, P. L. (Aerospace Med. Div., Brooks Air Force Base, Texas), W. D. Hurt and J. C. Mitchell. *Med Instrumentation* 7(3):185-188, 1973.

ECG tracings were made on 9 anesthetized dogs with atrioventricular blocks induced by injection of 10% buffered formalin and implanted demand cardiac pacemakers before and during exposure to microwaves (2450 MHz) at a distance of 370 cm from the sending horn. Power was continuously increased until inhibition or a change in rate occurred. Bench tests were performed under the same conditions on 10 implanted demand and synchronous pacemakers. Complete inhibition was observed on 4 of the 9 implanted pacemakers at thresholds of about 8 $\mu\text{W}/\text{cm}^2$. All nonimplanted pacemakers were inhibited by radiation, and 3 of the 10 showed inhibition at the lowest detectable level (0.8 $\mu\text{W}/\text{cm}^2$), indicating that complete inhibition might have occurred at a lower level. There were significant differences in susceptibility threshold levels among identical devices. Shielded models had a much higher threshold level than unshielded models. In dogs bradycardia and tachycardia were observed at various power density levels. This test shows potentially hazardous electromagnetic interference (EMI) can occur below 10 $\mu\text{W}/\text{cm}^2$. The effect of EMI was qualitatively the same on implanted and nonimplanted pacemakers, suggesting that each model has a typical response versus power density curve. (9 references)

0065 CLINICAL, MORPHOLOGICAL AND BIOCHEMICAL CHANGES IN EXPERIMENTAL MICROWAVE-INDUCED CATARACT. (Rus.) Grechushkina, V. A. (Helmholtz Sci. Res. Inst., Moscow, USSR). *Oftalmol Zh* 27: 226-228, 1972.

The effects of exposure to moderately intense ultrahigh frequency radiation (output power 60 watts, slit 9 cm, wavelength 12.6 cm, frequency 2375 MHz, diameter of the emitter 9 cm, 10-14 sessions of 15 min exposure each) were studied on 28 Chinchilla rabbits weighing 2-3.5 kg. These doses of radiation are comparable to those used clinically as moderate therapeutic doses in ophthalmologic practice. The left eye of each rabbit was exposed, while the right eye served as a control. Microwave-induced cataracts developed in 23 of these 28 rabbits. The lens became cloudy immediately after the course of radiation exposure in ten of the younger rabbits and within 3-7 days after radiation exposure in 13 of the adult

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animals. Microwave-induced cataracts were located in the posterior cortical layers in the horizontal suture. They were round or semicircular in shape and regressed in eight of the ten rabbits which were observed for 2-3 months. The remaining five rabbits were sacrificed immediately after radiation exposure to determine if any biochemical changes had occurred in the lens. In these rabbits the ascorbic acid content of the lens had decreased, but ascorbic acid contents were normal in the aqueous humor. No changes had occurred in dehydroascorbic acid contents. There was a significant decrease in the sulfhydryl group content in the soluble protein of the lens, but no change occurred in the content of total soluble protein. The decrease in the ascorbic acid and sulfhydryl group contents occurred simultaneously, suggesting that biochemical changes precede the development of microwave-induced cataracts. In the ten rabbits which had already developed cataracts, more pronounced decreases were observed in the ascorbic acid and sulfhydryl group content in the lens than in rabbits which had not yet developed cataracts. The ascorbic acid content had also decreased in the aqueous humor, as had the content of total soluble protein in the lens. Studies of seven rabbits in which microwave-induced cataracts had regressed revealed that all of these biochemical changes are reversible. Because these microwave-induced cataracts regress spontaneously and heat is not a very important factor with the moderate doses used here, the specific action of microwaves may play a role in the mechanism which results in cataract formation. (19 references)

0066 EFFECT OF INDUCTOTHERMY ON HEART FUNCTION IN PATIENTS WITH SYSTEMIC SCLERODERMA.

(Rus.) Malorova, I. S. (Ctr. Inst. Balneol. Physiother., Moscow, USSR). *Vopr Kurortol Fizioter Lech Fiz Kult* 37:448-450, 1972.

Of 91 patients with systemic scleroderma and cardiac involvement, 45 had cardiosclerosis, 34 had myocardiosis, and 12 had involvement of the heart valves. Clinical signs consisted of cardiac dilatation, dullness of the heart tones, a systolic murmur, and accentuation of tone II over the pulmonary artery. ECG findings included changes in the T wave (45 cases), low potentials of the main waves (30 cases), conduction disorders (31 cases), and changes in rhythm (23 cases). In combination with therapeutic gymnastics and massage, inductothermy was administered with an inductor cable, two coils of which were wrapped around the patient's body at the T₁₀-L₄ level and an anode current of 140-180 milliamps was applied for 10-15 min. Treatments were given 4 times a week (total of 12-16 sessions). This therapy reduced pain in the chest in 56% and alleviated dyspnea and made tachycardia disappear in 1/2 of the patients. ECG tracing showed improvements in conduction in 5 and normalization of rhythm in 12 patients. Analysis of the phase structure of systoles in the left ventricle showed improvement in myocardial contractility and increased efficiency of the systole in 29 cases; a decrease in compensatory ability due to deterioration in myocardial contractility in 34 patients; and a decrease in the efficiency of the systole due to

changes in the phase structure of systoles in the left ventricle in 28 patients. (5 references)

0067 SCREENING FOR CATARACTS. (E.) McAfee, R. D. (Univ. Sch. Med., New Orleans, La.), L. L. Cazenavette and M. G. Holland. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) Sept. 1973, p 3B2/1.

A shadow-graph is described which allows a subject to view his own eye for opacities. The device has been tested at an eye clinic, and the results of its use by cataract patients who have drawn their own opacities are compared with follow-up by photo-slit lamp examinations. In an ongoing survey, the shadow-graph is being used for cataract screening of veterans who have been exposed to microwave radiation as a result of a specific service-connected job such as radar repairman or an aircraft handler on aircraft carrier flight decks.

0068 METHOD OF MEASUREMENT OF RADIO FREQUENCY INTERFERENCE FROM MICROWAVE OVENS. (E.) MacLachlan, A. S. (Ministry Posts Telecommunications, London, England). *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) Sept. 1973, p 5B3/1-5B3/2.

Microwave ovens are a potential source of interference to radio services over the whole range of frequencies up to 7000 MHz. Because an oven forms an imperfect screen, some of the radio-frequency energy produced escapes by conduction along the main lead or by radiation through imperfect door seals and ventilation slots. In Europe measurements of interference at 0.15-30 MHz are made with a quasi-peak RF voltmeter at the main terminals. Radiated interference can also be measured using an RF voltmeter. The measurements are usually made using a magnetic loop aerial in the range up to 30 MHz, a dipole aerial for 30-1000 MHz, and a small-aperture horn aerial above 1000 MHz.

0069 ADVANCES IN CHOKE DESIGN FOR MICROWAVE OVEN DOOR SEALS. (E.) Osepchuk, J. M. (Raytheon Res. Div., Waltham, Mass.), J. E. Simpson, and R. A. Foerstner. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) Sept. 1973, p 5B4/1-5B4/11.

By introducing periodic or quasi-periodic loading in the door seal region, new slotted choke designs for microwave oven door seals confine modes exciting choke resonance to TEM and inhibit transverse mode propagation. The new designs yield maximum leakage values at 2.0" below 0.10 mW/cm² fairly consistently. Leakage distribution curves for 15 microwave ovens with the slotted choke show a mean of 0.0537 mW/cm² with only a few units above 0.10 mW/cm². Field data show little increase in leakage over a 1-2 yr period.

0070 INTERLOCK SYSTEMS FOR MICROWAVE OVENS. (E.) Prucha, R. V. (General Electric Co., Louisville, Ky.). *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) Sept. 1973, p 5B21/

15B2/2.

A number of interlock systems found in household microwave ovens in the United States are reviewed and a description of methods is presented. Design objectives are discussed and the relative merits of various approaches are illustrated using the method of "fault tree analysis." Simple interlock systems have been replaced by redundant systems to guard against component failures, latched systems to ensure that power is removed before the door seal is disturbed, and concealment schemes to ensure that the interlock system is not defeated deliberately or accidentally. More sophistication may be required. There have been instances where simple redundancy did not guard against common mode kinds of induced failure. Systems must be studied for freedom from common mode failure. In addition, the concept of an interlock monitoring function is being advanced. This concept is also related to a disablement function which renders apparatus incapable of generating microwave energy until it has been tended by a service specialist, if the monitor detects a malfunction.

0071 THE COMBINED EFFECT OF A SUPERHIGH-FREQUENCY FIELD AND AN UNFAVORABLE MICROCLIMATE ON THE BODY. (Rus.) Zhuravlev, V. A. (No affiliation). *Voen Med Zh* (3):64-67, 1973.

Experiments were performed on young female rats which were exposed to microwaves in the 10-cm range (5 milliwatts/cm²) for 1 hr/day and then were placed in an incubator at 40°C and a relative humidity of 22-25%, were exposed to the same unfavorable microclimate but were not irradiated, or were neither irradiated nor exposed to heat. After 60 days these females were mated with normal males to study the effect of these conditions on their reproductive function. Exposure to heat and microwaves increased the RBC, WBC, and hemoglobin content of the blood, whereas heat alone tended only to increase the RBC. The specific gravity of the blood remained essentially unchanged in both groups. The viscosity of the blood and blood catalase activities decreased in both treated groups, but the decrease was more pronounced in rats exposed to both microwaves and heat. While exposure to heat alone had no effect on the percentage of rats producing progeny (87.5%) or on the mean number of offspring per liter (8.9), only 50% of the females exposed to heat and microwaves produced offspring and the mean number of offspring per litter was 6.5. While controls gave birth to more females than males, the sex ratio was reversed for rats exposed to microwaves and heat and for those exposed to heat alone. Autopsies revealed that weight coefficients for the liver and spleen were significantly lower than control values in rats exposed to both microwaves and heat. Histological examinations of the myocardium showed that homogenized and fragmented muscle fibers and small subepicardial hemorrhages were present in rats exposed to microwaves and heat, while rats subjected to heat alone had signs of circulatory disorders (congestion, stromal edema, etc.). Chronic venous congestion was more pronounced in livers and spleens from rats exposed to microwaves and heat. (No references)

0072 CHANGE IN THE NUMBER OF TOTAL SULFHYDRYL GROUPS IN THE BLOOD OF SUBJECTS WHO COME INTO CONTACT WITH GENERATORS OF SUPERHIGH-FREQUENCY RADIATION. (Rus.) Kolesnik, F. A. (No affiliation) and N. A. Komogortseva. *Voen Med Zh* (3):63-64, 1973.

Amperometric titrations with 0.001 M silver nitrate solutions were used to determine the concentration of -SH groups in the blood of subjects who come into contact with generators of superhigh-frequency (SHF) radiation and of controls. All subjects were 20-40 yr old, and those exposed to SHF radiation had been employed in their positions for 1-10 yr. The mean concentration of -SH groups was 920 μ M/100 ml in controls, 698 μ M/100 ml in those exposed for 1-2 yr, and 768 μ M/100 ml in those exposed for 2-10 yr. Since exposure to SHF radiation significantly decreases blood -SH group concentrations, this test can be used to diagnose the initial stages of disorders caused by SHF radiation. Administration of cysteamine (0.4-1.2 g) significantly increased blood -SH group levels in both controls and workers exposed to SHF radiation, while administration of ascorbic acid (0.5 g) had no effect on blood -SH group levels. It is recommended that cysteamine be used prophylactically in subjects exposed to SHF radiation. (No references).

0073 ANALYSIS OF REPORTED PHYSIOLOGIC EFFECTS OF MICROWAVE RADIATION. (E.) McLees, B. D. (Naval Med. Res. Inst., Bethesda, Md.) and E. D. Finch. *Advances Biol Med Phys* 14:163-223, 1973.

The interaction between electromagnetic waves and tissue is described with emphasis placed on the water content of the tissue. Techniques used to measure the dose of microwave radiation are considered, and temperature changes induced by whole-body, partial-body, and experimental human exposure to microwaves are reviewed. In thermal doses microwave exposure consistently produces changes in the WBC. Changes in the RBC suggest that microwaves induce mild hemolysis, but the data are not conclusive. Changes in reticulocyte counts and isotope kinetics have been variable, and insufficient evidence has been obtained to indicate that microwave exposure causes hemolysis or bone marrow depression. Microwave irradiation has decreased blood volume and produced changes in serum protein, venous CO₂, and chloride levels, but the last two changes cannot be explained until serum electrolytes, arterial blood gases, and pH are investigated. Exposure of rabbits to microwave radiation until a critical temperature had been reached affected production of antibodies to sheep RBC, but investigations at lower power levels are needed to gain insight into the nature of these antibody changes. The effects of microwaves on the endocrine system, particularly the testes, are reviewed, and brief consideration is given to possible mutagenic effects. Systems for inducing cataracts with microwaves are discussed, relationships between cataract formation and intraocular temperature and power

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density are reviewed, and metabolic changes occurring in the eye during microwave irradiation are considered. Although most American and Western European investigators believe data on low-level nonthermal effects of microwave radiation are not valid, a wide variety of such effects are reported in the Eastern European literature. Most of these effects involve the CNS and do not appear to depend upon the frequency of the radiation but on the peak power density. (80 references).

- 0074 CHANGES IN INTRALEUKOCYTE PEROXIDASES IN INTRAARTICULAR EXUDATES AFTER IRRADIATION WITH RADAR MICROWAVES. (It.) Santolini, B. M. (San Giorgio Inst. Orthopedics, Genoa, Italy), P. L. Nal Fovino and L. Rossoni. *Minerva Ortopedica* 22:459-462, 1971.

The technique of Stato and Sekija was used to determine peroxidase activity in WBC of intraarticular exudates from 12 patients with rheumatoid arthritis. Samples were exposed to radar microwaves *in vitro* immediately after they were obtained. Exudates from 6 patients were exposed to microwaves for 5, 15, or 30 min with the power held constant at 150 watts, while those from the remaining 6 patients were irradiated for 10 min at powers of 50, 100, and 150 watts. The peroxidase activity in WBC decreased only in exudates irradiated at 150 watts for 30 min. No changes were observed in any of the other samples exposed for shorter periods. These findings confirm that radar therapy has a beneficial local effect in rheumatic inflammation when it is used in the proper doses. (26 references)

- 0075 MORPHOLOGICAL STUDIES OF THE COAGULATION EFFECTS OF 8-MM MICROWAVES IN THE RABBIT EYE. (Ger.) Lommatzsch, P. (Ophthalmol. Clin., Humboldt U., Berlin, Germany), B. D. Böhne, W. D. Ulrich and R. Kuhn. *Albrecht von Graefes Arch Klin Ophthalmol* 187:201-214, 1973.

Ophthalmoscopic and histological examinations were performed on rabbits after irradiation with pulsed (duration ca. 80 nanosec) microwaves (wavelength 8.15 mm) from a generator equipped with a hollow adaptor designed to fit the curvature of the eye. The emergent power ranged from 0.1-2.5 watts, and exposure times were 30 and 60 sec. By measuring the increase in temperature occurring during irradiation in a water phantom, it was demonstrated that coagulation produced by 8-mm microwaves can be accounted for by thermal effects. Because of the rapid decrease in temperature as the distance between the eye and the generator was increased, a relatively large increase in temperature was obtained primarily in the outer layer of the sclera. Histological findings resembled those previously observed with high-frequency diathermy. Scleral fibers were swollen, and there was proliferation of the surrounding connective tissue at higher powers. Clearly defined chorioretinal scars formed at lower powers, suggesting that 8-mm microwaves might be used for surgical correction of detached retinas. (28 references)

- 0076 SUSCEPTIBILITY OF CARDIAC PACEMAKERS TO RADAR INTERFERENCE. (E.) Rohl, D. (U. Ulm, W. Germany), H. M. Laun, M. E. T. Hauber, H. Voigt and M. Staunich. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) Sept. 1973, p 4B1/1-4B1/2.

The susceptibility of 16 cardiac pacemakers to radar interference was investigated. All pacemakers showed signs of interference at effective pulse power densities between 25 $\mu\text{W}/\text{cm}^2$ and 6250 $\mu\text{W}/\text{cm}^2$. Metal-shielded and unshielded pacemakers were equally sensitive in air because the interfering radiation was received through the electrode in both types. Pace-makers implanted in dogs and patients were disturbed in the vicinity of a high-power radar station. To reduce interference susceptibility, a very sensitive unshielded pacemaker was modified by metal-shielding and a low-pass filter at the electrode. Thereafter it was insensitive to effective pulse power densities of $> 12 \text{ W}/\text{cm}^2$ when tested under worst-case conditions in air.

- 0077 MECHANISM INVOLVED IN THE BIOLOGICAL ACTION OF ULTRASOUND AND SUPERHIGH FREQUENCY ELECTROMAGNETIC FIELDS IN THE 3-CENTIMETER RANGE. (E.) Sivorinovskii, G. A. (Ctr. Inst. Balneother. Physical Ther., Moscow, USSR). *Vopr Kurortol Fizioter Lech Fiz Kult* 38:222-227, 1973.

Oxidative phosphorylation was studied in rat liver and kidney mitochondria before and after irradiation of the abdomen with pulsed (2700 impulses/sec) microwaves (power densities of 25, 50, and 100 microwatts/cm²) for 10 min. A single exposure to 25 microwatts/cm² had no effect on oxygen consumption and respiratory control in rat liver mitochondria but did decrease the effectiveness of phosphorylation somewhat. In kidney mitochondria respiratory activity decreased slightly, respiratory control increased, and the effectiveness of phosphorylation remained unchanged. Ten exposures to this power density of microwave radiation increased the rate of oxygen consumption and respiratory control in kidney mitochondria. A single exposure to 50 microwatts/cm² decreased phosphorylating activity in liver mitochondria but had no effect on that in kidney mitochondria. Ten exposures to this power-density of microwave radiation increased respiratory control in both liver and kidney mitochondria. A single exposure to 100 microwatts/cm² increased oxygen consumption and decreased the effectiveness of phosphorylation in rat liver mitochondria and increased respiratory control but had no appreciable effect on phosphorylation in kidney mitochondria. The rates of oxidative phosphorylation approached normal values in both liver and kidney mitochondria when rats received 10 exposures at this power density. No correlation was found between blood sugar levels and the functional activity of mitochondria when rats were repeatedly exposed to 100 microwatts/cm² radiation. Since repeated exposure to microwaves in the 3-cm range had less effect than a single exposure on oxidative phosphorylation in liver mitochondria, it is suggested that some of the enzymes involved in this process adapt to microwave exposure. (19 references)

0078 GASTROINTESTINAL FUNCTION IN WORKERS EX-
POSED TO THE EFFECTS OF ELECTROMAGNETIC
FIELDS IN THE ULTRAHIGH FREQUENCY RANGE. (Rus.)

Kleiner, A. A. (Inst. Industrial Hyg. Occupational
Dis. Khar'khov, USSR). *Gig Tr Prof Zabol* (2):15-18,
1974.

Gastrointestinal function was investigated in 72 workers in radio and television centers who had been exposed to 5-10 times the maximum permissible levels of electromagnetic radiation in the meter range (UHF). Of these workers, 69% were men and 62% were less than 40 yr old. The duration of exposure was less than 5 yr in 16 cases, between 5 and 10 yr in 27, and more than 10 yr in 29. Occupationally related functional disturbances of the nervous and cardiovascular systems were diagnosed in 69%. Controls consisted of 43 normal subjects who had never been exposed to occupational hazards. Among the radio and television workers clinical symptoms of gastrointestinal disease (epigastric pain, postprandial discomfort, nausea, heartburn, decreased appetite, belching, and evacuatory disorders) tended to increase in frequency with increasing occupational exposure to UHF radiation. Although no disorders were observed in basal gastric acid or protein secretion or in the volume of gastric juice secreted, response to mechanical or chemical stimulation was reduced in the majority of cases. Although clinical diagnosis of chronic gastritis had been established in 12 subjects (16.6), stomach biopsies from 17 workers showed that 5 had only superficial gastritis and 11 had normal findings. Almost all of the 5 patients with gastritis had been exposed to UHF for more than 10 yr. The amplitude of gastric contractions was reduced in 41.2%. Pancreatic enzyme secretion recovered slowly after stimulation with 30 ml of 0.5% hydrochloric acid. Blood levels of Atoxyl-resistant lipase and trypsin were significantly increased and blood amylase levels increased after double glucose loading. Although none of the workers had symptoms of liver disease, liver function tests showed that 1/2 had disorders in protein secretion, 58% had disorders of carbohydrate metabolism, and 33% had impairment of hepatic detoxification. The Meltzer-Lyon test was positive in 1/5 of the workers and bile concentrations of bile acids tended to be low while bile cholesterol levels were higher than in the control group. Disorders in bile synthesis were most pronounced among workers who had more than 10 yr exposure to UHF radiation. (12 references).

0079 BIOLOGICAL EFFECTS AND EXPOSURE STANDARDS
FOR NON-IONIZING ELECTROMAGNETIC ENERGIES.

(E.) Michaelson, S. M. (U. Rochester Sch. Med.,
N.Y.). 3rd Int. Congress of Int. Radiation Protection Assn. (Washington, D. C.) September 9-14,
1973.

Nonionizing radiant energies at certain frequencies, intensities, and durations of exposure can produce biological effects which may be beneficial as well as harmful. For the general population and those persons exposed or with potential exposure to these energies, personnel exposure guidelines and product emission standards have been promulgated for some of

these energies. Personnel protection guides or exposure standards are usually those established by the American National Standards Institute, American Conference of Government Industrial Hygienists, or Department of Defense. Some industrial organizations have standards of their own which may be modifications of the national standards. Legislation for personnel exposure and product emission levels for nonionizing radiation are covered under the Occupational Safety and Health Act of 1970 and the Radiation Control for Health and Safety Act of 1968, resp. It is important that a distinction be made between product emission standards and personnel exposure standards and how they relate to potential injury. Realistic assessment of the biomedical effects of these radiant energies is essential so that the worker or general public will not be unduly exposed, nor research, development, and beneficial utilization of these energies be hampered or restricted. There are areas of disagreement between Eastern European and Western investigators on the effects of radio frequency and microwaves. USSR and Eastern European standards are based on vague "asthesia" syndromes reported by individuals who work with microwave/radio frequency energies. These effects have not been demonstrated by Western researchers. (55 references)

0080 LENTICULAR AND RETINAL CHANGES SECONDARY
TO MICROWAVE EXPOSURE. (E.) Aurell,

E. (Dept. Ophthalmol., U. Gothenburg, Sweden) and
B. Tengroth. *Acta Ophthalmol (Kbh)* 51(6):764-771,
1973.

Eye examinations were carried out on 98 employees in an electronic industry developing radar equipment. Of this number 68 subjects had been exposed to microwaves for a certain period or were still working in the field; the remaining 30 had no known exposure. The number of exposed subjects with lens opacities was high, even in age groups under 41 yr. Retinal lesions were also frequent in the exposed group but were found in only 1 employee in the control group. Dividing the exposed group into testing personnel and laboratory personnel revealed a significantly higher concentration of lens and retinal lesions in the former. This concentration in a certain exposed group suggests that the recommended maximum permissible exposure of 10 mW/cm² is probably sufficient and that the lesions were due to leakages from equipment or carelessness on the part of testing personnel. In two cases the lesions resulted in a decrease in vision. Damage to the retina suggests that similar changes might appear in other nervous tissue after exposure to microwaves. (41 references)

0081 DO YOU HEAR WHAT I HEAR? (E.) Hindin, H.
J. (no affil.). *Microwaves* 13(2):9, 1974.

Experiments conducted by Allan H. Frey and Rodman Messenger, Jr. of Randomline, Inc., Willow Grove, PA are described. Field tests with radar have indicated that humans perceive low-power, pulse-modulated energy in the 0.3-3 GHz band. In radio-frequency anechoic chamber experiments, subjects with normal hearing were trained to estimate the perceived loud-

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ness of the buzz heard at 1.245 GHz. A randomized order of peak power, average power, pulse width, and pulse repetition rates were used. The results show that once a minimum pulse width is achieved, perceived loudness is a function of peak power only. When pulse width is held constant and average power varied, the sounds perceived vary in timbre and pitch. The threshold for perception in the radio-frequency chamber was a peak power of about 80 mW/cm². The mechanism of detection of microwave energy by humans is not known but may involve interaction of microwave, electromagnetic and neural fields. (No references)

0082 HAZARDS-RESEARCH COORDINATION. (E.)
Anonymous. (no affil.). *Microwave J*
17(3):32, 1974.

Intensification of research on microwave radiation health effects, with improved communication among world scientists, may result from the first International Symposium on Biologic Effects and Health Hazards of Microwave Radiation, held October 15-18, 1973 in Jadwisin, Poland. A major discrepancy to be resolved between Western and Eastern scientists concerns microwave power levels at which health effects may be expected. Because of differences in findings, maximum occupational exposure levels in the United States are as much as 1000 times the levels permitted in Russia and Eastern Europe. Following the presentation of 40 papers on microwave radiation subjects, the Symposium recommended (1) the promotion of international coordination of research on the biologic effects of microwave radiation; (2) development of a nonionizing radiation program by an international health agency; (3) establishment of internationally acceptable nomenclature and definitions of physical quantities and units, and standardization of measurement techniques and dosimetry; (4) use of operational definitions of microwave intensity ranges to achieve a more uniform approach to the discussion of mechanisms underlying biological effects; and (5) furtherance of biologic, medical, epidemiologic, and bio-physical studies to improve understanding of the interaction of microwave radiation with biologic systems. (No references)

0083 BIOLOGICAL EFFECTS IN RODENTS EXPOSED TO
10⁸ PULSES OF ELECTROMAGNETIC RADIATION.
(E.) Skidmore, W. D. (Armed Forces Radiobiol.
Inst., Bethesda, Md.) and S. J. Baum. *Health Phys*
26(5):391-398, 1974.

Sprague-Dawley rats and AKR/J mice were exposed for 38 weeks to 10⁸ electromagnetic pulses (EMP) at 5 pulses/sec and a peak electric field intensity of 447 kV/m. Reticulocyte count in exposed rats were often significantly greater than that of non-irradiated animals. However, there were no concomitant differences in peripheral erythrocyte counts between the two groups, nor did radioactive iron incorporation indicate increased cellular production in the irradiated group. While platelet counts in exposed rats were about 10% below those in the nonexposed group, the two groups did not differ in number of circulating leukocytes or bone marrow

cellularity. Analysis of chromosomes from bone marrow cells showed no detectable increases of aberration in EMP-exposed rats; chemical analysis of blood and histological studies indicate no effect of EMP. Rat fetuses showed no abnormalities, and no mammary tumors were observed in exposed rats. Exposure to EMP did not induce an early onset of spontaneous leukemia in male AKR/J mice, nor was the fraction of leukemic mice greater in the exposed group (9/42) than in the nonirradiated group (11/24). Exposure of rodents under conditions in excess of that encountered by humans who handle EMP facilities indicated no apparent acute injuries. (17 references)

0084 MICROWAVE IRRADIATION SACRIFICE: APPLI-
CATION IN NEUROCHEMICAL RESEARCH. (E.)
Schmidt, D. E. (Tennessee Neuropsychiatr. Inst.,
Nashville), M. J. Schmidt, F. A. Robinson and L. K.
Wilson. *Proc Int Microwave Symp* June 1973, p 326-327.

Temperatures, inactivation rates of adenylyl cyclase, phosphodiesterase, cholinesterase, and levels of acetylcholine and cyclic AMP were measured in rat brain following microwave sacrifice. Temperatures of 70-80 C were reached in 15-20 sec in a 200-250 g rat. Inactivation of enzyme systems was rapid and simultaneous throughout the brain. Acetylcholine, choline, and cyclic AMP values were interpreted as approaching true *in vivo* brain levels. It is concluded that microwave irradiation sacrifice reduces presacrifice and sacrifice stress in animals as compared with decapitation and/or freezing. Design and construction of a more powerful focused microwave system should reduce inactivation time to under 1 sec and further reduce or eliminate stress. Such a system will allow the most accurate determination of true *in vivo* levels and turnover rates of heat stable neurotransmitters to date. (5 references)

0085 POSSIBILITIES FOR CONTROLLING STORED-GRAIN
INSECTS WITH RF ENERGY. (E.) Nelson,
S. O. (Agric. Eng., Univ. Nebraska, Lincoln). *Proc
Microwave Power Symp* May:201-202, 1972.

Studies of the effects of radiofrequency and microwave energy on insects are reviewed. The influence of physical and entomological factors is summarized on the basis of experimental evidence. Physical factors discussed include frequency, field intensity, modulation, exposure time, dielectric properties of insects and grain, moisture content and other characteristics of the host medium. Entomological factors include insect species, developmental stage, age, nature of injury and effects on reproduction when insects are exposed to high-frequency fields. The frequency dependence of the relative dielectric constant and loss factor is illustrated as determined by measurements on bulk insects and bulk grain samples throughout the range 250 Hz to 12.2 GHz. Data are presented on relationships between sample density and dielectric properties for hard red winter wheat and adult rice weevils, and estimates are given for dielectric properties of wheat kernels and individual insects at about 10 GHz. Estimates of relative field intensity are obtained

modeling insects as spherical objects in an infinite medium. Analyses indicate that the range 5-100 MHz offers the best possibility for insect control through selective or differential dielectric heating. (No references)

- 0086 THE ENVIRONMENTAL IMPACT OF MICROWAVE SYSTEMS IN THE 70'S. (E.) Jansky, D. M. (Off. Telecommun. Policy, Exec. Off. President, Washington, D.C.). *Proc Int Microwave Symp* June 1973, p. 184-185.

Users of Government and non-Government microwave systems are documented together with the types of services they perform and the magnitude of powers employed. Projected advances in microwave technology during the 1970's include a new spectrum for space services and integrated circuit microwave components which will permit the development of inexpensive equipment, applicable to a number of different systems. These advances will have two major environmental impacts, one of which is electromagnetic compatibility and the other biological. Existing communication-electronic equipment may be susceptible to functional modification by the radio energy of new communication-electronic systems. Therefore, the introduction of new systems increasingly demands prior proof of electromagnetic capability. Considerable research has been undertaken to ascertain the potential biological impact of radio energy. Boundary conditions that will be protective of health, while permitting the functioning of telecommunication systems, are discussed. (No references)

- 0087 THERMAL EFFECTS OF SINGLE AND REPEATED EXPOSURES TO MICROWAVES - A REVIEW. (E.) Michaelson, S. M. (U. Rochester Sch. Med., N.Y.). *Proc Int Symp Biologic Effects Health Hazards of Microwave Radiation* (Poland) October 15-18, 1973, Report No. UR-3490-317.

Although few studies of repeated exposures to microwaves are available, there are some that show interesting relationships in respect to threshold phenomena and physiologic adaptation. Threshold response is noted in rabbits exposed to 2.45, 5.40, 8.23 and 10.05 GHz localized to the eye at power density/time durations sufficient to result in opacities. Adaptive reactions have been noted in the dog, rabbit, and cat. For example, repeated whole-body exposure to 2.88 GHz and 1285 MHz pulsed microwaves at power densities from 20-165 mW/cm², 1-6 hr/day for 2-4 weeks, showed thermal adaption or acclimatization as reflected by diminished temperature response as the exposures continued. Rats repeatedly exposed to 2.45 GHz pulsed reveal adaptive reaction of functional changes. Acetylcholine levels in the blood of rabbits and functional changes such as arterial pressure alterations in rabbits also show the phenomenon of adaptation as a result of repeated exposures to thermogenic levels of microwaves. These studies are of interest not only from the viewpoint of microwave biologic effects and health implications, but also as a means of examining some fundamental aspects of thermoregulation, acclimatization or adaptation, and interrelated cardiovascular, biochemical, and neuroendocrine functions. (84 references)

- 0088 A PROPOSAL FOR A MICROWAVE RADIATION WARNING SIGN. Ghosh, S. K. (Radiation Protection Bureau, Hazards Control. Div., Health Welfare Canada, Ottawa), A. M. Muc, D. W. Lecuyer and M. P. Diotte. *Health Phys* 26(4):360-361, 1974.

One way to reduce exposure to microwave radiation would involve the posting of warning signs which would be specific to microwave radiation hazards and would indicate the hazard both qualitatively and quantitatively. Based on the concept used by the Canadian Department of Consumer and Corporate Affairs, a system of three such signs is proposed. A triangular sign indicating CAUTION MICROWAVES would indicate the presence of microwave fields which are sufficiently low (less than 1 mW/cm²) to allow UNLIMITED OCCUPANCY under normal conditions. A diamond-shaped sign indicating WARNING MICROWAVES would indicate areas in which the power density exceeds 1 mW/cm² and within which LIMITED OCCUPANCY would be allowed. An octagonal sign indicating DANGER MICROWAVES would indicate areas in which the power density exceeds 25 mW/cm², or DENIED OCCUPANCY zones. For microwave devices, the CAUTION sign would indicate a device whose normal use requires care, while the WARNING sign would indicate devices which could cause injury and the DANGER sign would indicate devices which could cause death. (2 references)

- 0089 THE MICROWAVE OVEN SAFETY DEBATE. De Vore, R. T. (Bureau Radiological Health) and A. Van de Griek. *FDA Consumer* p. 25-26, Apr. 1973.

In April 1973, the Consumer Union announced that it could not recommend any of the home model microwave ovens now on the market, largely because they leak detectable radiation. However, since all electronic devices generating almost all types of electromagnetic radiation leak some detectable radiation, the Bureau of Radiological Health, which maintains that the microwave ovens manufactured today are safe for home use, states that the most feasible approach to electronic radiation protection is to require that electronic radiation emissions be kept well below the lowest levels known to cause biological effects. The Federal microwave oven standard sets a maximum emission standard within such limits. While this standard allows for some deterioration of the oven during its useful life, properly cared for ovens may undergo little change in radiation control capabilities as the result of use. The Consumer Union unfavorably compares the FDA standard for microwave oven emissions with the Russian standard for microwave exposure of an individual. The maximum allowable emission level at the source and the actual exposure received are not the same, however, and the FDA standard is actually more stringent than the Russian requirement. The microwave oven standard is continually reviewed and, when warranted, improved by the Bureau of Radiological Health. (No references)

- 0090 RADIO-FREQUENCY ENERGY: A HAZARD TO WORKERS? (E.) Odland, L. T. (Radiol. Hlth. Lab., Wright-Patterson Air Force Base, Ohio), V. T. Penikas, and R. B. Graham. *Ind Med Surg*

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July/August:23-26, 1973.

A statistical summary of results of ophthalmological examinations conducted on individuals whose occupations provided a potential for exposure to the radio-frequency portion of the electromagnetic spectrum is presented. Studies were conducted on 697 individuals (320 controls) during the period December 1970 to April 1972. Criteria for selection of participants were that the individual be primarily engaged in the operation or maintenance of radar equipment. The main criterion in the selection of controls was that the individual was not and had not been engaged in any duties that permitted an actual or potential opportunity for repeated exposure at the occupational level to electromagnetic radiation other than that of background and visible light. The data considered relevant to the purposes of the study were: age, family history, and three indices of lens changes; opacities, vacuoles, and posterior subcapsular iridescence (PSCI). In the control group, 33 of 320 had no recordable lens changes in either eye as compared with 40 of 377 in the study group. In the control group; 89 individuals had positive family histories (siblings, parents, or grandparents) of diabetes mellitus, nontraumatic cataract, glaucoma, and/or grossly defective vision as compared with 99 in the study group. Both groups were well matched for age with the mean age for both groups being 35. Frequency of lens changes between the two groups were similar with PSCI the most frequently observed change. The only notable difference in the study was that in controls 17% had positive family histories and lens changes as opposed to 29% in the study group. No conclusions were reached with respect to this difference since there was no record of actual exposure for each individual in the study group. To judge the significance of the occupational hazard of electromagnetic radiation more accurately, it will be necessary to correlate medical findings from long-term observations of workers exposed to electromagnetic radiation with the extent of exposure. (9 references)

0091 DETERMINATION OF ENERGY ABSORPTION OF MICROWAVE RADIATION USING THE COOLING CURVE TECHNIQUE. (E.) McRee, D. I. (Nat'l. Inst. Environ. Health Sci., Research Triangle Park, N.C.). *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) Sept. 1973, p 4B5/1-4B5/3.

Cooling time-temperature profiles of a simulated biological specimen in a test tube were measured after the 2450 MHz microwave field was terminated. From these cooling curves, the loss and absorption coefficients were determined. Using these coefficients, the time-temperature profiles and energy absorption during exposure can be mathematically calculated. A comparison of the calculated time-temperature profiles and the measured time-temperature profiles is presented. The cooling curve technique has usefulness in biological effects studies. The amount of energy absorbed or dose to the specimen can be determined without having a detector in the specimen during irradiation. The calculated time-temperature profiles allow the investigator to treat control specimens to the same time-temperature

conditions. Thus, nonthermal or specific effects of microwave irradiation can be evaluated. (No references)

0092 DETERMINATION OF THE ABSORPTION OF MICROWAVE RADIATION BY A BIOLOGICAL SPECIMEN IN A 2450 MHZ MICROWAVE FIELD. (E.) McRee, D. I. (Nat'l. Inst. Environ. Hlth. Sci., Research Triangle Park, N.C.). *Health Phys* 26(5):385-390, 1974.

Research into the bioeffects of microwave radiation requires accurate measurements of fields and doses to the specimen to provide information of value for determining safe exposure levels. A technique is presented for determining the energy absorbed by a biological specimen in a laboratory situation. Time-temperature profiles for 5 ml of distilled water were measured using a thermistor tested for its insensitivity to the 2450 MHz continuous wave microwave field. The time-temperature profiles are accurately described by a mathematical equation derived from absorption and loss coefficients at a single known power density. After obtaining the mathematical model for a particular experimental situation, the model can be used to determine the time-temperature profile for any power density level. While primarily applicable to *in vitro* studies where the biological specimen is small and relatively homogeneous, the technique could be extended to specific tissues in animal systems where small probes are implanted. (7 references)

0093 FUNCTIONAL AND MORPHOLOGICAL STUDIES OF THE THYROID GLAND IN ANIMALS EXPOSED TO MICROWAVE IRRADIATION. (E.) Baranski, S. (Military, Inst. Aviation Med., Warsaw, Poland), K. Ostrowski and W. Stodolnik-Baranska. *Acta Physiol Pol* 23(6): 1029-1039, 1972.

Functional and morphological changes in the thyroid gland and in ultrastructure of secretory cells were studied in 20 adult rabbits irradiated 3 hr/day for 4 months with microwaves of pulsed modulation (wavelength 10 cm, power density 5 mW/cm²). Chronic irradiation, at a dose not causing an elevation of total and local temperature, induced a 100% increase in the indexes of conversion and protein-bound ¹³¹Iodine, which indicates increased secretion of thyroid hormone. Increases in ¹³¹I incorporation into the thyroid gland (50%), the differential absorptive ratio (70%), and radioactivity of dry thyroid mass (70%) were related to increased production of hormone in the thyroid, as confirmed by autoradiographic studies. In histological sections, thyroid follicles were covered by high cuboidal epithelium. No mitotic figures were observed. Electron microscopy revealed an increased number of cytozomes, enlargement of the Golgi apparatus, and endoplasmic reticulum. These studies confirm the possibility of extrathermic action of microwaves and cumulation of doses of radiation through a long period of time. (17 references)

0094 EFFECT OF AN ELECTROMAGNETIC FIELD IN THE METER RANGE ON THE NERVOUS SYSTEM OF ANIMALS ON THE BASIS OF PHYSIOLOGICAL AND BIOCHEMICAL STUDIES. (Rus.) Goncharova, N. N. (Inst.

Industrial Hyg. Occupational Dis., Khar'kov, USSR) and L. I. Mishchenko. *Gig Tr Prof Zabol* (7):22-25, 1973.

Changes in defensive conditional reflexes and biochemical changes in the brain were studied in rats exposed for 4 months to nonthermal magnetic and electrical fields in the meter range. Rats were divided into 5 groups and were exposed to electrical fields with intensities of 800 and 200 volts/m and magnetic fields with intensities of 2 and 1 amps/m, resp. The remaining group consisted of nonexposed controls. Exposure to electrical and magnetic fields increased the latent period of conditional reflexes. This increase reached a maximum after 4-6 wk of exposure. The latent time then decreased but was still significantly longer than in controls after 4 months. Summation threshold values also tended to increase with exposure to 800 volts/m and 2 amps/m. This increase reached a maximum after 8-12 wk of exposure. The extent of the increase depended upon the intensity of the field. When exposure was discontinued, both the latent period and summation threshold values returned to normal. Exposure to an electrical field at an intensity of 800 volts/m decreased the glycogen content of the brain but had no effect on its glucose content; increases in lactate and pyruvate occurred in the brain and blood. Exposure to a magnetic field increased the glycogen content of the brain by 21% but had no effect on other parameters of carbohydrate metabolism. Thus, exposure to an electrical field apparently stimulates glycolysis and interferes with oxidation of carbohydrates while exposure to a magnetic field inhibits carbohydrate metabolism. During exposure to an electrical field with an intensity of 800 volts/m the preformed ammonia content of the brain increased by an average of 37.5%; decreases were noted in the other groups. In a number of cases these metabolic disorders persisted for several weeks after discontinuation of exposure. Although no change was produced in the total acetylcholine content of the brain by exposure to electrical (800 volts/m) or magnetic (1 amp/m) fields, changes did occur in the distribution of acetylcholine fractions in the former group. Bound acetylcholine decreased by 84% while the free or loosely bound fraction increased by 134%. Acetylcholinesterase activity decreased in all groups except the one exposed to a magnetic field with an intensity of 1 amp/m. These findings suggest that binding of acetylcholine with lipoprotein is impaired and its synthesis may be inhibited. The decrease in acetylcholinesterase activity is apparently secondary to the decrease in its substrate. (6 references)

0095 RATE EFFECTS IN ISOLATED HEARTS INDUCED BY MICROWAVE IRRADIATION. (E.) Lords, J. L. (Microwave Device Physical Electronics Lab., U. Utah, Salt Lake City), C. H. Durney, A. M. Borg and C. E. Tinney. *IEEE Trans Microwave Theory Tech* MTT-21(12):834-836, 1973.

Continuous wave 960-MHz microwave irradiation of isolated turtle hearts in Ringer's solution produced bradycardia rather than the tachycardia usually induced by generalized heating. The effect

occurred over the range of 50 to 200 mW total input power, with the greatest decrease in heart rate occurring at 100 mW. This corresponds to an estimated 3 mW absorbed by the heart. It is hypothesized that the microwave power stimulated the nerve remnants and/or the *boutons terminaux* causing the release of transmitter which induced the decrease in heart rate. (2 references)

0096 POWER DEPOSITION IN A SPHERICAL MODEL OF MAN EXPOSED TO 1-20 MHz ELECTROMAGNETIC FIELDS. (E.) Lin, J. C. (Univ. Washington Sch. Med., Seattle), A. W. Guy and C. C. Johnson. *IEEE Trans Microwave Theory Tech* MTT-21(21):791-797, 1973.

The induced fields and the associated power deposition in man exposed to high frequency (HF) electromagnetic fields were investigated theoretically using spherical models. The induced electric fields inside the model exposed to plane wave or near fields can be described adequately by a combination of quasi-static electric and magnetic induction solutions. For field impedances less than $1200\pi\Omega$, the magnetically induced energy absorption predominates. Therefore, H fields must be measured to obtain any estimate of the hazards due to HF exposure. For a 70-kg model of man exposed to a plane wave field, the theory indicates that the time-average power absorption/unit volume is less than 2.5×10^{-3} mW/g for each milliwatt/square centimeter incident at 20 MHz and below. This suggests that the thermal safe-exposure levels for the HF band are many orders of magnitude in excess of the 10 mW/cm^2 level recommended for the microwave region. (12 references)

0097 1. ISOTROPIC ELECTRIC FIELD PROBES FOR COMPLICATED FIELDS. (E.) Bowman, R. R. (Natl. Bur. Standards, Boulder, Colo.). *Digest of Papers Joint US Army/Georgia Inst Technol Microwave Dosimetry Workshop* 1-2 June, 1972, p 53-55.

A field sensor for complicated electric fields is completely independent of its orientation in the field despite any combination of reactive near-field components, multipath components, and arbitrary polarization. The sensor consists of three electrically short, orthogonal, dipole-diode antennas that separately sense the corresponding orthogonal components of the electric portions of the electromagnetic field. The three detected signals are transmitted away from the sensor by conductors of such high resistance that they are essentially transparent to the electromagnetic field. Preamplifiers buffer these signals which are then summed in a scaling amplifier with three nonlinear inputs. The composite signal provided is proportional to the electric field energy density at the position of the sensor. Practical probes utilizing this sensor are within 1 dB of isotropic. Electromagnetic hazard meters with greater than 40 dB dynamic ranges and wide frequency ranges have been developed from these probes. (no references)

0098 STUDIES OF RF BIOLOGICAL HAZARDS FROM HIGH POWER TRANSMITTERS OPERATING IN THE

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HF BAND. (E.) Kall, A. R. (Ark Electronics Corp., Willow Grove, Pa.). *Proc IEEE 1973 Electromagnetic Compatibility Symp* June 1973, p 53.

The results of two separate research programs are reported concerning intensive investigations into biological radio frequency hazards from high power, high frequency (HF) transmitting antennas. The programs consisted of two major phases: measurement of field strengths in the near vicinity of HF band antennas, and coordinated clinical irradiation studies on laboratory rats. The clinical studies established threshold values for E and H fields, and a level for the combined ExH field that is within the experimental error range of the ANSI limit of 10 mW/cm². Discussion of electronic irradiation techniques and the nature of the biological investigations are included. (No references)

0099 BASIC PRINCIPLES FOR SHIELDING ELECTROMAGNETIC FIELDS. (Rus.) Maksimenko, N. V. (Khar'kov Sci. Res. Inst. Industrial Hyg. Occupational Dis., USSR), G. I. Evtushenko and N. N. Goncharova. *Gig Sanit* 38:108-110, 1973.

Experimental investigations on reducing the field strength of pulsed and continuous electromagnetic fields produced by high-frequency generators showed good agreement between experimental data and theoretical values calculated for different wavelengths by the method of D. E. Shapiro (see graph for further details). According to this method, the effectiveness of continuous shielding is given by $4.2 E_M \times R/\lambda$, where λ is the wavelength of the electromagnetic field in meters, E_M is the shielding effectiveness of the material, and R is the radius of the shield (spherical). (6 references)

0100 THE DEVELOPMENT OF SOME MICROWAVE MEASURING TECHNIQUES IN THE PAST 25 YEARS. (Ger.) Groll, H. (no affil.). *Nachrichtentechnik* 26(8): 352-353, 1973.

The evolution of microwave signal generators and receivers is briefly reviewed with consideration of techniques for measuring power, transmission, adjustment, impedance and frequency. (No references)

0101 EFFECT OF MICROWAVES ON BIOLOGICAL SUBSTRATES. (Fr.) Berteaud, A. J. (Lab. Magnetism, CNRS, Bellevue, France). *Electron Fise Appli* 16(3):517-522, 1973.

The effects of microwaves on a biological substrate depend upon the dielectric properties of the substrate which contains large quantities of water (average of more than 70%). However, water interacts with various components in the substrate by forming bonds with them, the strength of which depends upon the extent of hydration. Microwaves are generally absorbed by water as a result of Debye relaxation, and this absorption is manifested by a thermal effect which, in some cases, is too small to measure. Absorption of quanta of radiation with wavelengths in the millimeter range is responsible for changes in the rotational energy of molecules or

side chains of macromolecules having a permanent dipole moment. Mechanical effects exerted by microwaves on particles suspended in a liquid include (1) forces resulting from a nonhomogeneous field, (2) orientation of nonspherical particles, and (3) formation of chains of spherical particles. The electrical properties of these particles are analyzed mathematically. (4 references)

0102 THERMAL AND ATHERMAL EFFECTS OF 2.8 GHZ MICROWAVES ON THREE HUMAN SERUM ENZYMES. (E.) Belkade, M. L. (Hlth. Protect. Branch, Hlth. Welfare Canada, Ottawa), A. M. Muc, and D. L. Johnson. *J Microwave Power* 9(1):23-29, 1974.

The effects of microwave radiation *in vitro* on the human serum enzymes lactate dehydrogenase, acid phosphatase, and alkaline phosphatase were investigated. Serum specimens were treated with 2.8 GHz microwaves (1 kHz mW/cm²) at an incident power density of 400-1000 mW/cm². Treatments with and without microwaves were carried out in a heat exchanger at 37 C, 46.7 C, and 49.7 C for 4-1/2 or 18-1/2 min. Enzyme activities were determined and analyzed for the possible thermal or athermal effects of the microwave radiation. Inactivation of each of the three enzymes occurred following either 4-1/2 or 18-1/2 min treatment with and without microwaves at 49.7 C, the longer treatment generally producing greater inactivation. The relative activity difference between the irradiated and nonirradiated sample groups was not statistically significant for any of the three enzymes. These results suggest that the microwave field did not cause any athermal denaturation of the irradiated enzymes and that thermal denaturation was responsible for the observed inactivation. (13 references)

0103 I. MICROWAVE IRRADIATION AND THE CIRCADIAN RHYTHM OF BONE MARROW CELL MITOSES. (E.) Czerski, P. (Natl. Res. Inst. Mother Child, Warsaw, Poland) and E. Paprocka-Slonka. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) Sept. 1973, p 2B1/1-2B1/2.

Changes in the amplitude and phase of the circadian rhythm of the bone marrow mitotic index were observed in Swiss albino mice exposed for 4 hr to 2950 MHz pulsed microwaves (1200 Hz, 1μs) at 0.5 ± 0.2 mW/cm² power density. The changes were demonstrable 24 and 48 hr after exposure and regressed 72 hr after exposure (damped oscillation). (2 references)

0104 II. MICROWAVE IRRADIATION AND THE CIRCADIAN RHYTHM OF BONE MARROW CELL MITOSES. (E.) Czerski, P. (Natl. Res. Inst. Mother Child, Warsaw, Poland), E. Paprocka-Slonka and A. Stolarsak. *J Microwave Power* 9(1):31-37, 1974.

Changes in the amplitude and phase of the circadian rhythm of the bone marrow mitotic index were observed in Swiss albino mice following 4-hr irradiation at 2.95 GHz. The mean power density was 0.5 mW/m² and comprised 1.0 μs pulses at a repetition frequency of 1.2 KHz. Bone marrow smears were air-dried, stained with May-Grunwald-Giesma stain, and

mitoses/1000 cells were counted. Recognizable granulocyte precursor and erythroblastic mitoses were classified as such; the remaining mitoses (early erythroblasts, myeloblasts, and lymphocytes) were grouped as "stem cell" mitoses. Differences between irradiated animals and controls were wholly accounted for by stem cell mitoses. No significant differences between the two groups were noted in mitotic indexes of granulocyte precursors and erythroblasts. Temperature measurements did not differ significantly in irradiated and control animals. It is concluded that low-level microwaves do not interfere with the process of cellular division, but induce a response of stem cells probably dependent on physiologic attributes of the cell group. (10 references)

0105 EXPOSURE OF BIOLOGICAL SPECIMENS TO HIGH POWER HF BAND FIELDS. (E.) Frazer, J. W. (USAF Sch. Aerospace Med., Brooks AFB, Tex.), J. C. Mitchell, A. E. Gass, and W. D. Hurt. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada), May 1972, p 167-168.

Primates and rodents were exposed to fields of 5000 V/meter at 10.5, 19.7, and 26.6 MHz, with the maximum rise in body temperature occurring at 26.6 MHz. Primates so exposed have shown no ill effects in over 1 yr. A transient sensitivity of lymphocytes to phytohemagglutinin as a division initiator is being investigated, but seems not to have been associated with long-term effects. Neonatal mice were exposed to fields of 5-7000 V/meter acutely on the 4th day postpartum at 10.5, 19.7, and 26.6 MHz. Without additional stress, there was no difference between growth curves in exposed and control groups. When small amounts of n-propanol were injected s.c. prior to exposure, a growth delay in the radiated group showed that precise experimental conditions must be met to demonstrate an effect of HF band fields on growing animals. (No references)

0106 PERCEPTION AND AVOIDANCE OF ILLUMINATION WITH LOW POWER PULSED UHF ELECTROMAGNETIC ENERGY. (E.) Frey, A. H. (Randomline, Inc., Willow Grove, Pa.) and S. Feld. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) May 1972, p 130-135.

Experiments were conducted to determine the sensory and behavioral effects on Sprague-Dawley rats of illumination with low power pulse modulated UHF energy. Carrier frequency was 1.245 GHz; pulse width, 30 μ s; and pulse repetition rate, 100 pps. The rats were exposed in an anechoic chamber containing two barrier boxes arranged so that one was lower and offset to the front and side of the other cage. The right half of the lower cage and the left half of the higher cage were shielded from the UHF energy. The average power density illuminating the unshielded half of the lower box was 0.4 mW/cm²; the shielded half was exposed to 2% of the unshielded level. The unshielded half of the upper box was exposed to 0.9 mW/cm² average power density, the shielded half to 7% of this level. Test data indicate that rats perceive free field illumination with low power modulated UHF electromagnetic energy, find it aversive, and are

actively motivated to avoid it. The animals responded equivalently to the 0.4 mW/cm² power level in the lower box and the 0.9 mW/cm² level in the upper box. This indicates that the perceptual and aversive threshold is less than 0.4 mW/cm² average power density and less than 133 mW/cm² peak power density. The effect appeared within the first 15 min of test sessions, persisted through the entire 90-min session, and was consistent over 7 days of testing. (7 references)

0107 DIELECTRIC STUDIES ON BIOLOGICAL MATERIALS NEAR 1 GHz: BIOPHYSICAL AND MEDICAL IMPLICATIONS. (E.) Grant, E. H. (Phys. Dept., Queen Elizabeth Coll., London, England). *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) Sept. 1973, p 1B2/1-1B2/2.

A linear relationship between the permittivity of blood at 2 GHz and its hemoglobin concentration is reported. This linearity could become the basis of an electrical method for measuring hemoglobin concentrations. Other measurements on LDL β -lipoproteins at 800 MHz showed significant differences in permittivity between samples from normal patients and patients with hyperbetapoproteinemia. The most likely explanation of these differences is that normal lipoprotein samples have a very low value for the water of hydration (<0.06), whereas abnormal samples require a hydration between 0.07-0.17). (No references)

0108 ELECTROMAGNETIC PULSE RADIATION: A POTENTIAL BIOLOGICAL HAZARD? (E.) Milroy, W. C. (Naval Weapons Lab., Dahlgren, Va.), T. C. O'Grady and E. T. Prince. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) Sept. 1973, p 3B1/1-3B1/2.

Concern has arisen over the bioeffects of electromagnetic pulse radiation (EMP) due to the very high field densities involved, i.e., hundreds of thousands of volts/meter. No significant effects were observed in an Air Force pilot study involving several dogs, a monkey, and maze-trained mice. A Russian study of EMP effects on humans showed an intensity-time relationship on the appearance of phosphenes in the visual field. In a study being conducted by the Armed Forces Radiobiological Research Institute, a large rat population is continuously irradiated by a pulsed field of ~500 kV. The population is being monitored for a variety of physiological parameters; no significant results have been obtained thus far. In addition to these experimental studies, reviews of health records of several hundred workers at EMP generator facilities have shown no significant bioeffects. (No references)

0109 COMPUTATION OF PERSONNEL EXPOSURE IN MICROWAVE LEAKAGE FIELDS AND COMPARISON WITH PERSONNEL EXPOSURE STANDARDS. (E.) Osepchuk, J. M. (Raytheon Res. Div., Waltham, Mass.), R. A. Foerstner, and D. McConnell. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) Sept. 1973, p 4B4/1-4B4/2.

The meaning of personnel exposure to microwave radiation in the context of U.S. and Eastern Euro-

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pean exposure standards is reviewed. From data on personnel location *versus* time and the nature of leakage spatial distribution, an upper limit to personnel exposure was computed based on several worst-case assumptions. An application to consumer oven usage is presented. The HEW emission limit insures very high safety factors for the case of localized leakage. In cases where the prime leakage occurs over a substantial area like a door screen or conveyor tunnel, the computed safety factors would be lower because of slower decrease of fields with distance. In conceivable industrial situations the emission standards proposed by IMPI would ensure operator exposure even below that of Eastern Europe. (No references)

- 0110 THERMOREGULATORY, CARDIOVASCULAR AND METABOLIC RESPONSE OF RATS TO SINGLE OR REPEATED EXPOSURES TO 2450 MHz MICROWAVES. (E.) Phillips, R. D. (Batelle Lab., Richland, Wash.), N. W. King, and E. L. Hunt. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) Sept. 1973, p 3B5/1-3B5/4.

Physiological measurements were made on young male rats immediately after single and repeated exposures to 2450 MHz microwaves (pulsed at 120 Hz) in a cavity arrangement that produced absorption of energy at 11.1 mw/g. Acclimation was evident in animals that received 10 exposures over a 2-week period. Incomplete heart block occurred in 67% of rats exposed only once to microwaves, compared with a 22% incidence in repeatedly exposed animals. Abrupt bradycardia developed in single-exposure animals, whereas animals that received repeated exposures had a regular heart rate through the test period. The magnitude of hypothermia was also greater in animals exposed once to microwaves. Oxygen consumption and carbon dioxide production were equally depressed (25%) in both exposed groups. Respiratory quotients were normal in the two groups. Results for a second experiment indicated that the degree of acclimation was dose-dependent. Less acclimation was noted in an additional group of animals exposed at 6.2 mw/g for nine 30-min sessions followed by a 10th session at 11.1 mw/g. (13 references)

- 0111 MICROWAVE RADIATION HAZARDS CONTROL PROGRAM IN THE U.S. ARMY. (E.) Taylor, J. R. (U.S. Army Environ. Hyg. Agency, Edgewood Arsenal, Md.). *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) May 1972, p 31-32.

The microwave control program in the U.S. Army is directed by the Army Environmental Hygiene Agency, which is an activity of the Army Surgeon General's Office. Every installation where Army personnel, military or civilian, could be exposed to radiated energy from microwave generating equipment would be surveyed to determine if a potential hazard exists. The standards used in the U.S. Army establish the safe exposure limit as any level below 10 mW/cm² and the denied exposure limit as 100 mW/cm² or greater. Between these two limits there is an allowable exposure period that applies only when mission function precludes shutting down the transmitting

system. Performance standards are outlined for microwave ovens, and measurement of microwave leakage and visual inspection must be performed at least once a month. Operators of diathermy units are instructed to maintain certain controls and perform several checks prior to their use. One such control is that the unit can be used only at the direction of a physician. Radar systems receive the closest scrutiny; field measurements using power and power density meters are performed. Where measurements are impractical, calculations are conducted. In all cases controls are implemented to prevent exposure to power densities greater than 10 mW/cm². (2 references)

- 0112 EXAMINATION OF THE CORNEA FOLLOWING EXPOSURE TO MICROWAVE RADIATION. (E.) Williams, R. J. (Natl. Naval Med. Ctr., Bethesda, Md.) and E. D. Finch. *Aerosp Med* 45(4):393-396, 1974.

Microwave irradiation of New Zealand rabbits with 2450 MHz continuous wave or 2860 MHz pulsed at an average power field density of 225 mW/cm² given daily for 20-30 min for up to 5 weeks had no detectable effect on the normal or the wounded cornea. In control corneas about 1 in 80 basal epithelial cells incorporated tritiated thymidine. Neither the number nor pattern of cells undergoing DNA synthesis in the normal and wounded cornea was altered by radiation. The wound healing process in corneas irradiated daily while healing was similar to that in corneas irradiated for 4 weeks prior to wounding. Because of the relationship of the depth of penetration of energy into the tissue to the frequency of the radiation, higher frequencies might be more efficient in producing thermal damage in the corneal epithelium. At 10,000 MHz, 50 mW of power would be absorbed by the cornea compared with 4 mW at 2450 MHz. Thus, further investigation into the effects of radiation at higher frequencies is warranted. (9 references)

- 0113 CONTINUOUS EXPOSURE OF CHICKS AND RATS TO ELECTROMAGNETIC FIELDS. (E.) Giarola, A. J. (Dept. Electr. Eng., Texas A & M Univ. College Station) and W. F. Krueger. *IEEE Trans Microwave Theory Tech* MTT-22(4):432-437, 1974.

Growth rate and feed consumption depression were observed in groups of 25-day-old male chicks when exposed in metal cage environments to the following continuous wave fields: a UHF wave at 880 MHz in a very low-Q cavity resonator energized by a 220-mW power source; a VHF wave at 260 MHz in a very low-Q cavity resonator energized by a 220-mW power source; an extremely low frequency (ELF) electric field at 45 or 60 Hz with calculated electric field strength of 3500 V/min; an ELF magnetic field at 45 or 60 Hz with 1.3 G. After 23 days exposure to the UHF field at 880 MHz, treated chicks had an average body weight of 217.0 g compared with 245.0 g for controls. Continuous 21-day exposure to a VHF field (260 MHz) reduced growth about 5% compared with comparable controls. Exposure of chicks to the ELF magnetic field depressed growth rate by 9-11% in comparison with nonexposed controls. Adrenal

glands of chicks exposed to the 880-MHz wave were smaller (18.03 mg) than those in control chicks (23.22 mg). Growth depression was also observed in rats exposed to the UHF field at 880 MHz from birth to 43 days of age. Mean adrenal weights of treated and control rats did not differ significantly, but spleen and thymus weights of the treated rats were notably larger. Potential causes of the observed growth depression could be localized RF currents, resulting from animal-to-metal wall contact and transmitted to body tissue. (12 references)

- 0114 CHICK EMBRYO DEVELOPMENT IN A 26-KHZ ELECTROMAGNETIC FIELD. (E.) Zervins, A. (Westinghouse Res. Labs., Pittsburgh, Pa.). *Am Ind Hyg Assoc J* 34(3):120-127, 1973.

Sixty-two fertilized chicken eggs (White Leghorn) were exposed for the first 19 days of incubation to a 26-KHz, 160- gauss peak-to-peak a.c. field. Seventy similar unexposed eggs were maintained under the same environmental conditions. Of the exposed eggs, 64.5% hatched, while 48.5% of the unexposed eggs hatched. None of the dead embryos showed evidence of gross abnormalities or teratology and all of the hatched chicks appeared normal within the first 36 hours after hatching. Of 20 exposed and 16 control chicks which were maintained to adulthood, all grew normally and exhibited normal behavior patterns. Among the hatched chicks, a 50-50 sex ratio was observed. The results do not support the hypothesis that embryos exposed to an electromagnetic field have less chance of hatching than non-exposed embryos. (23 references)

- 0115 AMENDMENTS TO THE US DEPARTMENT OF HEALTH, EDUCATION AND WELFARE MICROWAVE OVEN PERFORMANCE STANDARD. (E.) Van De Griek, A. (U.S. Dept. Health Educ. Welfare, Rockville, Md.). and R. G. Britain. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) Sept. 1973, p 4B3/1-4B3/2.

The Department of Health, Education, and Welfare microwave oven performance standard is being amended, as a result of 2 yr of field experience and testing, to add explicit power density limits to each required interlock and to require a monitor which will prevent oven operation subsequent to interlock failures. The primary interlock is required to terminate microwave generation before leakage at 5 cm from the oven surface exceeds the prior-to-acquisition limit of 1 mW/cm². The secondary interlock is required to terminate microwave generation before leakage exceeds the post-acquisition limit of 5 mW/cm². (No references)

- 0116 EFFECT OF MICROWAVE RADIATION ON THE NASTIC RESPONSE OF SOME SENSITIVE PLANTS. (E.) Bigu del Blanco, J. (Queen's Univ., Kingston, Canada), C. Romero-Sierra, and J. A. Tanner. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) Sept. 1973, p 3B6/1-3B6/2.

The effect of CW microwave radiation on the nastic response of some sensitive plants (e.g., *Mimosa pud-*

ica) were investigated. Experiments were conducted at X-band microwave frequencies (mainly 9.2 GHz) of low field intensities. During microwave radiation of 20 min or less, gradual but large changes were observed in the orientation of leaflets, leaves, and petiole. Dramatic changes were evident immediately after offset of the radiation. The more marked effects included the collapse of some petiole and the sudden reorientation of leaves and leaflets. In all cases complete recovery occurred between 20-30 min after offset of the microwave field. The results clearly emphasize the complex interaction between electromagnetic fields and biological systems. (3 references)

- 0117 AN OVERVIEW OF THE PROBLEM OF MICROWAVE HAZARD MEASUREMENTS AND DOSIMETRY. (E.) Grove, H. M. (Walter Reed Army Inst. Res., Washington, D.C.). *Digest of Papers Joint US Army/Georgia Inst Technol Microwave Dosimetry Workshop* 1-2 June, 1972, p 1-2.

The area of measurement and dosimetry is critical to investigations of biological effects and hazards of nonionizing radiation. Consistent dosimetry has not been achieved as evidenced by differences in safety standards in Eastern Europe and the West. The first of at least three levels of the nonionizing dosimetry problem is the hazards survey-type measurement where accuracy is not an overriding consideration. Instrumentation is available but reasonable quantities of the instruments are needed. A more serious problem is instrumentation to support research into the nature of biological effects. The present $\pm 1/2$ db accuracies are inadequate for dynamic ranges of 60 to 120-150 db of variation due to natural causes such as R² space loss, fading, multipath, and atmospheric attenuation. In the case of bioeffects, a 25% uncertainty is not acceptable considering the sensitivity of the biological system to count quanta of light or the analogue in audition and olfaction. The third area is the complex problem of personal dosimetry aimed at indication of integrated exposure of individuals in the industrial hygiene setting. In addition to these questions of field and dose, there is the problem of making temperature and electrophysiological measurements under irradiation. (No references)

- 0118 DESIGN OF A PYROELECTRIC MICROWAVE DOSIMETER. (E.) Bassett, H. L. (Eng. Exp. Station, Georgia Inst. Technol., Atlanta) and G. K. Huddleston. *Digest of Papers Joint US Army/Georgia Inst Technol Microwave Dosimetry Workshop* 1-2 June, 1972, p 10-11.

A pyroelectric probe has been developed for power density measurements at 1-10 GHz and for accurate measurements of field intensity close to and far from a radiator, both inside and outside of biological specimens. The probe operates on the principle of direct energy absorption in a lossy substance rather than as an antenna *per se*, with a pyroelectric crystal serving as the detector of absorbed energy. The crystal element is a slab of triglycine sulfate cut such that the broad faces are perpendicular to the spontaneous polarization axis. Conduct-

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ing electrodes are placed on the two broad faces to form a small, parallel-plate capacitor. The detector is connected to a preamplifier which serves to transform the rather high impedance of the pyroelectric detector to a low impedance to facilitate further instrumentation. Amplitude-modulated microwave energy incident on the probe is converted to thermal energy via ohmic losses in the crystal, which in turn causes the temperature distribution of the crystal to vary periodically at the same frequency as the modulation waveform. A pyroelectric current is produced which is proportional to the rate of change of temperature with time. The corresponding voltage produced between the electrodes is applied to the input of the preamplifier. (No references)

- 0119 BRAIN TEMPERATURES AND EEG DATA ACQUISITION FROM ANIMALS DURING MICROWAVE EXPOSURE. (E.) Larsen, L. E. (Walter Reed Army Inst. Res., Washington, D.C.). *Digest of Papers Joint US Army/Georgia Inst Technol Microwave Dosimetry Workshop* 1-2 June, 1972, p 4-5.

Results from bench test studies of conventional temperature and EEG transducers in microwave environments are reported. The temperature sensor was fitted with PtIr lead wires and potted into a tubular glass mount. The glass test chamber containing the mount was filled with physiological saline and placed inside an S-band waveguide. Each time the penetration or configuration of the mount was changed, the E-H tuner was adjusted for zero reflected power with 22 mW/cm² transmitted power density. The response consisted of a faster (10⁻¹ sec) and a slower (10⁰ sec) apparent heating. The former is artifactual since it is virtually coincident with onset of the fields and represents a faster heating than that which could actually take place at the incident power density. The slow phase is a mixture of slow artifact and real heating of the medium. The rate of increase of apparent temperature depended on penetration; and for a fixed depth of penetration, the rate of increase was markedly reduced by copper pipe shielding. The fast artifact was apparently due to the thin loop formed by lead wires in series with the thermistor; the slow artifact was due to a short dipole with parallel arms. The EEG transducers studied were chronic skull screws. The preparation was 4% agar gel contained in a polyfoam block, while the microwave environment was a plane wave S band carrier 100% amplitude modulated with a 10 Hz signal. The outputs with continuous wave fields on and off were indistinguishable. When the 10 Hz amplitude modulation was added, a 10 Hz signal at about 6 db voltage over the control was noted. The signal disappeared when electrodes were shortened and was lost in noise when the agar was withdrawn. (No references)

- 0120 PITFALLS IN MEASUREMENT OF ELECTROMAGNETIC FIELDS. (E.) Hollis, J. S. (Scientific Atlanta, Inc., Georgia). *Digest of Papers Joint US Army/Georgia Inst Technol Microwave Dosimetry Workshop* 1-2 June, 1972, p 3.

A presentation was made of the underlying principles of electromagnetic radiation and diffraction

which lead to problems in measurement of electromagnetic fields and particularly near-zone fields. The electromagnetic field parameters and Maxwell's equations were reviewed, the basic wave equation was introduced, and the concepts of traveling and standing waves were discussed. The process of summation of phasors was reviewed and this concept employed to illustrate far- and near-zone diffraction effects using the scalar diffraction integral. Polarization of electromagnetic waves, the concept of orthogonality of fields, and polarization efficiency in transfer of energy from a wave to a measuring probe were discussed from the viewpoint of the Poincare sphere. Simple electromagnetic field probes were shown and problems associated with their use in measurement of near-zone fields were described. (No references)

- 0121 EFFECT OF RADIOFREQUENCY CURRENTS ON STRICHNINE-INDUCED EPILEPTOGENIC FOCI IN THE CAT. (It.) Marchesi, G. F. (Clin. Neurol. Mental Dis., U. Perugia, Italy), C. Cianchetti, A. Casotto and F. Angelieri. *Boll Soc Ital Biol Sper* 48(19):535-539, 1972.

The effect of radiofrequency currents (frequency 4 MHz, power ranging from 0.1 to 10 watts) on experimentally induced epileptogenic foci was studied in 5 adult cats to determine whether these currents caused reversible or irreversible inactivation of the foci. Ten epileptogenic foci were induced in these cats by applying a disk of blotting paper, about 2-3 mm in diameter, which had been soaked in a 1% strichnine solution to a previously established point in the primary motor cortex which controlled the upper extremities. Simultaneous tracings were made of electrocortical activity and the electromyographic response of flexor and extensor muscles in the upper extremities. The radiowave current was applied to the epileptogenic foci by slowly increasing the power until the desired temperature value was reached. Temperatures of 45 C for 30 sec, 55 C for 15 sec, and 60 C for 10 sec were employed. At temperatures above 45 C, lesions produced in adjacent tissue were not reversible because coagulation had occurred. Coagulation was partial around 55 C and complete at 65 C. However, reversible inactivation occurred at 45 C. (14 references)

- 0122 ABSOLUTE PHYSICAL DOSIMETRY FOR WHOLE ANIMAL EXPERIMENTS. (E.) Hunt, E. L. (Battelle - Pacific Northwest Lab., Richland, Wash.) and R. D. Phillips. *Digest of Papers Joint US Army/Georgia Inst Technol Microwave Dosimetry Workshop* 1-2 June, 1972, p 74-77.

A whole-animal calorimeter was developed for measuring energy absorbed by fresh rat carcass during exposure to the microwave field in a multipath modal resonating cavity. Five pairs of carcasses in each of three weight groups were exposed to a 2.45 GHz source operated at a repetition rate of 120 pulses/sec. The 190 g carcass absorbed 434 ± 9 mW-min/W-min of cavity energy; the 290 g carcass, 482 ± 8 mW-min/W-min; and the 290 g carcass, 518 ± 8 mW-min/W-min. The average dose density decreased with increased carcass

mass and thickness. The smallest carcasses absorbed 2.29 ± 0.05 mW/g/W-min of available energy; the middle-sized carcasses, 1.67 mW-min/g/W-min; and the largest carcasses, 1.38 ± 0.01 mW-min/g/W-min. Within reasonable limits of animal body size, the system provides a practical laboratory standard for calibrating various exposure arrangements for whole-animal irradiation. (4 references)

0123 POTENTIAL MEDICAL AND BIOLOGICAL APPLICATIONS OF ELECTROMAGNETIC RADIATION. (E.)

Ecker, H. A. (Eng. Exp. Station, Georgia Inst. Technol., Atlanta). *Digest of Papers US Army/Georgia Inst Technol Microwave Dosimetry Workshop* 1-2 June, 1972, p 91-95.

Preliminary experiments indicate at least three potential medical and biological applications of electromagnetic radiation: selective heating of cancer tumors to enhance chemotherapy, thawing of frozen organs with electromagnetic radiation and microwaves for insect control. Differential hypothermia with selective electromagnetic heating and chemotherapy (5 fluorouracil) produced significant regression of spontaneous and chemically induced tumors in mice and rats. Brain tumors were treated with high frequency electromagnetic radiation (3-30 MHz) in combination with doping the tumor with high loss magnetic or ferrite material. This technique may be useful for treatment of cancer in most body tissues, without surgery. Rapid and uniform thawing of frozen canine kidneys was obtained using a combination of 2450 and 7 MHz radiation. Energy from the 7 MHz radiation produced heating from the center toward the surface of the kidney, while the energy from the 2450 MHz radiation produced heating from the surface to the center of the kidney. In insect control experiments, powder post beetle larvae and pupae were irradiated at 2450 MHz with a power density of 4.6 w/cm². Under these conditions, 100% mortality was attained for all radiation times greater than 5 min; 77% mortality was achieved with a 2-min radiation. Irradiation of cotton boll weevil larvae at 9100 MHz and 6 w/cm² power density produced 100% mortality for radiation times of 3 sec or greater and 53% mortality for 1 sec of radiation. (4 references)

0124 INFRARED THERMOGRAPHY IN MICROWAVE/BIOLOGICAL RESEARCH. (E.) Guy, A. W. (U.

Washington, Sch. Med., Seattle). *Digest of Papers Joint US Army/Georgia Inst Technol Microwave Dosimetry Workshop* 1-2 June, 1972, p 85-90.

Cross-sectional relative heating patterns in phantom models of tissue exposed to electromagnetic radiation were recorded with a thermograph camera. The temperature information was converted to normalized power absorption patterns and compared with theory. Thermograms and calculated absorption patterns are presented for phantom human limbs exposed to 915 MHz radiation, phantom cat or monkey brain exposed to 2450 MHz, and a phantom rat exposed to 500 MHz. Measured absorption patterns appearing in the center of phantom brain tissue compare favorably with that calculated from theory, verifying the existence of hot spots in the central nervous system exposed to

electromagnetic radiation. The results also clearly indicate that thermal effects can be produced in rats exposed to low level radiation even though other parameters such as incident power level, average absorbed power density, and core temperature of the animal would indicate otherwise. Thermograms were also obtained for an actual cat brain exposed to 918 MHz radiation. In the absence of a metal coaxial type physiological recording electrode in the animal's head, peak absorption corresponded to 2.27 mW/cm²/watt input power to the source of 2.5 mW/cm² of incident power density. Peak absorption measured with the electrode in place was 113 mW/cm², indicating the possibility of inducing thermal effects in the central nervous system by improper experimental protocol when using power density levels believed thermally insignificant. (1 reference)

0125 THE USE OF RF MAGNETIC PROBES FOR THE MEASUREMENT OF PENETRATION OF MICROWAVE ENERGY IN BIOLOGICAL SPECIMENS. (E.) Knott, E. F. (U. Michigan, Ann Arbor) and R. E. Hiatt. *Digest of Papers Joint US Army/Georgia Inst Technol Microwave Dosimetry Workshop* 1-2 June, 1972, p 82-84.

Enclosed system measurements of synthetic brain and synthetic bone at 1.0-5.5 GHz were carried out with six small radio frequency magnetic loop probes made from semi-rigid copper coaxial line. The probes were calibrated by supplying known values of field frequency and magnetic flux density threading the loop, then measuring effective voltage, thus determining coefficient C, i.e., probe area. Values of coefficient C show that, for certain fixed frequencies, all six probes behaved similarly. One probe had a fairly consistent response over all four frequencies tested and some came close to the theoretical C value of 23.8 mm². However, there is enough variation to warrant checking and calibrating the given probe before laboratory use. (No references)

0126 BIODOSIMETRY--THE SCALING OF MICROWAVE ENERGY BY BEHAVIORAL AND BIOLOGICAL RESPONSES. (E.) Justesen, D. R. (VA Hosp., Kansas City, Mo.). *Digest of Papers Joint US Army/Georgia Inst Technol Microwave Dosimetry Workshop* 1-2 June, 1972, p 78-81.

The efficiency with which individual rats discriminated complex modulated, 2450 MHz energy, as assayed by the technique of conditional suppression, was often highly correlated with microwave power as dosed in terms of mW/g of body weight (0.6 - 6.4 mW/g; "on-time" duty cycle = 6.7%). Rat behavioral response was reliably more sensitive than whole-body (colonic) thermal response to microwave irradiation. Even at a much higher level of energy dosing (~ 11 mW/g; duty cycle 50%) than the doses which efficiently cued a perceptual response, the mean of the peak hyperthermia of unrestrained rats was barely greater in irradiated than in sham-irradiated rats. The thermal data also indicate that psycho-physiological stressing led initially to an elevation of colonic temperature; further, restraint and irradiation in combination were apparently synergistic with respect

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to the hyperthermal response. It is suggested that data from classical studies of the lethal dose of irradiation are tainted by the compounding of stressors, including the stress of irradiation *per se*. (7 references)

- 0127 GHOSTS AND WITCHCRAFT IN RF MEASUREMENTS OR POWER ABSORPTION MEASUREMENTS IN FIELDS. (E.) Frazer, J. W. (USAF Sch. Aerospace Med., Brooks Air Force Base, Texas), J. C. Mitchell, A. E. Gass and W. D. Hurt. *Digest of Papers Joint US Army/Georgia Inst Technol Microwave Dosimetry Workshop* 1-2 June, 1972, p 56-73.

Experiments to determine power absorption by primates (Macacca Mulatta) suggested that the uncertainty of dosimetry in high frequency fields can be decreased by avoidance of close separation capacitors and more proper calculation of scattering in the wavelength region being used. Under conditions of wider separation of conductor and ground plane, power deposition in primates exposed to an electric field of 5880 V/meter and power density of 1.56 W/cm² was a function of frequency. Variation in precise power absorption was 3-9% of incident power density. A year after exposure to high intensity radio frequency fields, none of the primates used for thermal studies in high fields has shown evidence of lens opacities. Although a thermal effect was found in primates, rectal temperatures changed little, if at all, in rats exposed to an electric field of 5880 V/meter. Two systems of growth and maturation (mice neonates and *Tenebria* metamorphosis) revealed no demonstrable effects of 5880 and 10,000 V/meter fields, resp. In other experiments, pyridine nucleotides in eight brain areas were measured in rats exposed to 7000 V/meter continuous wave radiation at 24 MHz. Rapid microwave inactivation of enzymes was an appropriate analytical tool, but statistical variability was greater than any apparent differences between exposed and control rats. The consequence of power deposition from high frequency fields remains unknown, as does the nature of the charge carriers instrumental in absorbing the power. (8 references)

- 0128 THE DESIGN OF BROADBAND, RESISTIVE RADIATION PROBES. (E.) Hopfer, S. (General Microwave Corp., Farmingdale, N.Y.). *Digest of Papers Joint US Army/Georgia Inst Technol Microwave Dosimetry Workshop* 1-2 June, 1972, p 32-52.

A broadband microwave radiation probe is based on a finite resistive screen in free space. A resistive grid is formed by two noncontacting meandering lines deposited on two separate substrates. The lines are interconnected by through-holes in the substrates and form one continuous path which does not intersect itself. The resistive line is made up of alternating segments of bismuth and nichrome; these segments overlap slightly to form the thermoelectric junctions. By forming one continuous path, all thermocouples are connected in series to produce an output which is the sum of all the emf's generated by the individual couples. The resistive grid is sandwiched between two boron nitride discs and

contact between the discs and substrates is made only at the apparent intersection points. The discs are held together by a section of heat-shrinkable tubing and the overall assembly is encased in foam for further isolation from ambient changes and infrared radiation. The response of the probe at 1-18 GHz is plotted, as is response to an ambient temperature of 40 F. Full-scale ranges of the battery-operated probe extend from 0.2-200 mW/cm², with an overload capability in excess of 1 W/cm². Due to probe stability, meaningful measurements can be made at 10 μ W/cm². (6 references)

- 0129 DETERMINATION OF BIOLOGICAL TISSUE DIELECTRIC CONSTANT AND RESISTIVITY FROM IN VIVO IMPEDANCE MEASUREMENTS. (E.) Magin, R. L. (Eng. Exp. Station, Georgia Inst. Technol. Atlanta) and C. P. Burns. *Digest of Papers Joint US Army/Georgia Inst Technol Microwave Dosimetry Workshop* 1-2 June, 1972, p 12-31.

A new relatively simple technique permits the *in vivo* measurement of the physical parameters which determine absorption of electromagnetic radiation by biological tissues. The complex radio frequency impedance of tissue at 1-100 MHz is measured by a small probe which acts like a short antenna operating in a lossy medium. Utilization of an antenna impedance theorem allows the relative dielectric constant and resistivity of the tissue to be calculated. Measurements of *in vivo* brain and chemically induced tumor tissue were performed on laboratory rats. A table of power absorption, penetration depth, dielectric constant, and resistivity of brain and tumor tissue at 1-100 MHz is presented. The data show no resonance phenomena in this frequency which would enhance the selective heating of specific body tissues with respect to surrounding tissues. The calculation of penetration depths in the brain and tumor tissue shows relatively large values (approximately 10 cm) even at 100 MHz. Therefore, uniform heating can be expected at lower frequencies or for tissue sizes less than 10 cm. The electromagnetic power absorbed/unit volume in tumors is approximately twice that of brain tissue at 1-100 MHz. This result would enhance the selective heating of brain tumors by electromagnetic radiation at these frequencies. (8 references)

- 0130 EFFECT OF EPHEDRINE AND NIKETHAMIDE ON THE OUTCOME OF MICROWAVE-INDUCED DAMAGE IN MICE. (Rus.) Koldaev, V. M. (Vladivostok Med. Inst., USSR). *Biull Eksp Biol Med* 77(3):79-81, 1974.

Ephedrine (0.25-10 mg/kg i.v.), nikethamide (10-500 mg/kg i.v.), or a mixture of these 2 drugs (2 mg/kg ephedrine and 80 mg/kg nikethamide) was given to nonirradiated male albino mice which had been exposed to acute and chronic doses of microwaves. Mice were observed for 3 weeks after dorsal irradiation by the contact method using a power density of 62 \pm 5 milliwatts/cm² and a wavelength of 12 cm for 10-12 min. One group of mice were exposed for 10-12 min until they had reached a terminal state while the other was exposed for 5-6 min/day for 20 days. While

administration of ephedrine alone had no effect on the survival rate of mice exposed to a single large dose of microwaves, nikethamid increased the survival rate almost 1.5-fold. No synergistic effect was observed when the 2 drugs were given in combination. Mortality decreased and the total survival rate increased 1.6-fold when mice exposed to chronic doses of microwave radiation were given nikethamid. The survival time was longer in chronically exposed mice given ephedrine than in untreated controls, but ephedrine had no effect on survival rate. These findings indicate that respiratory stimulation with nikethamid increases the survival rate and has a favorable effect on regenerative processes occurring in mice after microwave-induced damage. (7 references)

- 0131 HARMFUL EFFECTS OF RADIATION FROM MICROWAVE OVENS. (Dan.) Ennow, K. (Radiation Hygiene Lab., Ministry Health, Copenhagen, Denmark). *Fra Sundhedsstyr* 22:277-279, 1971.

Problems relating to the establishment of safety standards for microwave ovens in Denmark are reviewed. Absorption of microwaves by tissue accelerates molecular motion, thus producing heat; the thermal effects of microwaves are most important biologically, although non-thermal effects also occur at high field strengths. Reports of nervous and cardiac disorders in Soviet radar operators, exposed to radiation at 0.01-1 mW/cm², remain controversial. Cataract development has been reported in persons exposed to microwave radiation from various sources, but no threshold values for this phenomenon have been established. A possible relationship has been demonstrated between radar exposure of fathers and the number of children with Down's syndrome. Serious consequences of microwave exposure included one case of vasculitis and one death due to intestinal damage three days after intensive microwave exposure. Measurements on commercial and home microwave ovens in the United States revealed that about one third had excessive radiation leakage. High radiation levels can occur following failure of the contacts designed to interrupt radiation production when the oven door opens. Three countries have proposed standards for microwave exposure, but these standards differ by a factor of 4000. (13 references)

- 0132 MECHANISM OF THE MICROWAVE EFFECT ON ERYTHROCYTE PERMEABILITY TO K⁺ AND Na⁺ IONS. (Rus.) Ismailov, E. Sh. (Dept. Human Animal Physiol., Dagestan State U., USSR). *Nauchnyi Dokl Vysshei Shkoly Biol Nauki* (3):58-60, 1971.

Human erythrocytes were exposed to microwaves (frequency 1009.076 MHz, power density 45 milliwatts/cm²) for 30 min in a thermostat so that the temperature did not exceed 37 C, and concentrations of K⁺ and Na⁺ in the solution surrounding the erythrocytes were measured by flame photometry. When erythrocytes were exposed to microwaves, the concentration of Na⁺ increased and that of K⁺ decreased in the cells. This effect was even more pronounced when erythrocyte solutions were incubated for 30 min after exposure to microwaves. Since about half of this movement was inhibited when moniodoacetate, an in-

hibitor of active ion transport, was added to the solution surrounding the cells, it is concluded that microwaves act both by increasing passive diffusion and active transport. This, in turn, may be caused by increases in the size of existing pores, the formation of new pores, or by changes produced in the ion radius by the hydrated membrane without any change occurring in the pore area in the erythrocyte membrane. (5 references)

- 0133 CHROMOSOMAL ABERRATIONS OF LIVING CELLS INDUCED BY MICROWAVE RADIATION. (E.) Chen, K. M. (Dept. Electr. Eng. Systems Sci., Michigan State U., East Lansing), A. Samuel and R. Hoopin-garner. *Environ Lett* 6(1):37-46, 1974.

Chinese hamster cells and human amnion cells were examined for the chromosomal effects of exposure to microwave radiation of 2.45 GHz at various intensities over various periods of time. Microwave-induced chromosomal aberrations in Chinese hamster cells with an initial temperature of 22 C included chromatid breaks, chromatid gaps, polyploidy, acentric fragments, deletions, and translocations. These aberrations were apparently nonthermal in nature since cell temperature was kept under 41 C. Cells preheated to 37 C required much lower radiation exposure (20-50 mW/cm²) to attain the degree of chromosomal aberrations observed in cells with lower initial temperature and exposed to higher radiation (50-80 mW/cm²). While some chromosomal aberrations and fragmentation were present two generations (48 hr) after exposure, chromosomal aberrations were significantly reduced after four generations (96 hr). This suggests that chromosomal damage due to microwave radiation can be repaired after a few generations. Some chromosomal aberrations were observed but no fragmentation was found in human amnion cells exposed to 2.45 MHz at an initial cell temperature of 22 C and final temperature of 37 C. These results indicate that an S-band microwave of moderate intensity has an effect on chromosomes of living cells. (11 references)

- 0134 II. ISOTROPIC ELECTRIC-FIELD PROBES FOR COMPLICATED FIELDS. (E.) Bowman, R. R. (Nat'l. Bur. Standards, Boulder, Colo.). *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) May 1972, p 29-30.

An electromagnetic hazard meter with an isotropic probe accurately measures the strength or intensity of complicated fields. The probe would be useful in measuring the fields within microwave ovens or within subjects or models exposed to high-power sources. In essence, the probe consists of three mutually orthogonal dipole antennas with a common center, a means for separately detecting the three RF signals induced across the dipole gaps, and a means for transmitting the three separate detected signals or a combined signal away from the dipole set without substantially perturbing the field to be measured or substantially affecting the operation of the dipole antennas. (No references)

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- 0135 THE EFFECT OF MICROWAVE RADIATION ON THE EYE. (E.) Aurell, E. (no affiliation). *Acta Ophthalmol (Kbh)* 51(5):742, 1973.

Of 54 workers occupationally exposed to microwaves, five were found to have central or paracentral changes in the eyeground. Two men were aware of paracentral scotomas and one had reduced visual acuity (VA = 0.7). The average age of the five men was below 30 yr. Investigations to test the hypothesis that these retinal changes are due to microwave radiation are in progress. (No references)

- 0136 COMPATIBILITY OF MEDICAL ELECTRONIC INSTRUMENTATION WITH THE ELECTROMAGNETIC INTERFERENCE ENVIRONMENT IN HOSPITALS. (E.) Kall, A. R. (Ark Electronics Corp., Willow Grove, Pa.). *Proc IEEE 1973 Electromagnetic Compatibility Symp*, June 1974, p 41.

The increasingly severe electromagnetic interference environment found in hospitals, together with electrical power line fluctuations, pose a dual problem for medical electronic instruments: assuring satisfactory operation of sensitive instrumentation within this hostile environment and assuring that newly introduced instruments do not create additional interference. Several typical case histories are presented. Techniques for measuring emitted interference and susceptibility are reviewed together with existing standards considered for application to the hospital environment and instrumentation. The essentials of a proposed standard specifically designed for this purpose are outlined. The correlative topic of electrical and radiation hazards is discussed briefly in relation to the general hospital electromagnetic environment. (No references)

- 0137 MATHEMATICS OF INTERACTION BETWEEN BLOOD AND ELECTROMAGNETIC FIELDS. (E.) Rashid, A. (Boeing Co., Kent, Wash.). *Proc IEEE 1973 Electromagnetic Compatibility Symp* June 1973, p 60-64.

The interaction between blood and electromagnetic energy is considered as a basic mechanism responsible for unexplained effects to the human system. Basic magnetohydrodynamic equations are derived which relate electric and magnetic field intensities to the velocity, density, pressure, and temperature of blood. Equations are also presented relating changes in these parameters to exposure to electromagnetic fields. No attempt has been made to solve the equations. (12 references)

- 0138 A METHOD OF MEASURING RF ABSORPTION OF WHOLE ANIMALS AND BODIES OF PROLATE SPHEROIDAL SHAPES. (E.) Gandhi, O. P. (Dept. Electr. Eng., U. Utah, Salt Lake City). *Proc Microwave Power Symp*, May 29-31, 1974 p B2-2/1-B2-2/4.

Radio frequency absorption of brain-phantom prolate spheroidal bodies of different aspect ratios was measured to 4000 MHz using a parallel plate waveguide. Results for mice and rats agree with the observed resonances of the prolate spheroids of aspect

ratios similar to these animals. Absorption observed at resonance for vertical orientation was an order of magnitude greater than for horizontal and longitudinal configurations. For prolate spheroids of aspect ratio 5.75, the temperature increase found for exposure to microwaves in the vertical direction is ten times higher than for the horizontal configuration. Important frequencies for maximum absorption for humans are derived by extrapolation as 40-55 MHz for vertical and 135-165 MHz for the other two configurations. (3 references)

- 0139 THERAPEUTIC APPLICATIONS OF ELECTROMAGNETIC POWER. (E.) Guy, A. W. (U. Washington Sch. Med., Seattle), J. F. Lehmann, and J. B. Stonebridge. *Proc IEEE* 62(1):55-75, 1974.

The use of electromagnetic (EM) power for therapeutic applications has existed since EM sources became available to man. Physical medicine has been a major user of both shortwave (27.33 MHz) and microwave (2450 MHz) diathermy over the decades in which EM power has been used to heat deep tissues to stimulate physiologic responses beneficial in the relief of certain pathological conditions. Experimental and clinical research indicates that these responses are obtained when tissue temperatures are raised 41-45 C, which requires absorbed power densities from 50-170 W/kg in the deep tissues. The combination of pain responses and a large reserve of blood cooling capacity seems sufficient for limiting the heating to safe but therapeutic levels in vasculated and innervated tissue. Recent research has shown that the industrial, scientific, and medical frequency of 915 MHz is more efficient than the currently used 2450-MHz frequency in terms of maximum power transfer to deep tissues. In addition to thermal applications, microwave energy can be used for controlled transcutaneous stimulation of nerve action potentials via implanted miniature microwave diodes. Stimulation is attained with absorbed power density levels as small as 0.0003 W/kg. (73 references)

- 0140 MODIFICATIONS OF IN VIVO RAPID MICROWAVE INACTIVATION OF ENZYMES IN THE CENTRAL NERVOUS SYSTEM. (E.) Lenox, R. H. (Walter Reed Army Inst. Res., Washington, D.C.), O. P. Gandhi, J. L. Meyerhoff, and P. V. K. Brown. *Proc Microwave Power Symp*, May 29-31, 1974, p A3-1/2-A3-1/5.

Advanced modifications over previously reported microwave methods for rapid inactivation of the brain are reported. The modified technique offers not only a more rapid inactivation of enzyme systems but also a significant improvement in the homogeneity of the microwave fixation process suitable for highly complex dissection. The system used is a WR430 waveguide driven by a Varian PPS 2.5 generator and terminating in a short-circuiting end-plate with a 3.8 cm diameter hole. To concentrate microwave power into the rat head and to obtain uniformity of field distribution over the longitudinal extent of the rat brain, the shorter dimension of the waveguide was gradually reduced to 3.8 cm by use of tapered aluminum plates. Uniformity of fields along the x-axis is obtained because of the dielectric loading

due to the rat head and the concentration of fields therein. Consistently uniform inactivation of the brain of 325-g rats was observed at 2.8 sec. The high degree of uniform inactivation throughout the brain has enabled measurement of cyclic 3'5'-adenosine monophosphate and cyclic guanosine monophosphate in 13 brain regions. (10 references)

- 0141 BIOLOGICAL EFFECTS OF MICROWAVES AND OTHER DIFFERENT FREQUENCIES. (E.) Richardson, A. W. (St. Louis U., Mo.). *Final Report Contract NR-102-362, Proj. Nonr-1304 (02), Nov. 1967, 12 p.* NTIS:AD 729379.

The results of an 11-yr research program on the biological effects of microwaves are summarized. Microwaves, whether continuous wave or pulsed (radar), are lethal with high energy and hazardous with low energy. Pulsed microwaves with a field density of 70 mW/cm² were lethal to albino rats with 30-min exposures. A field density of 25 mW/cm² over the head for 18 min produced extensive brain damage that was not overtly apparent. Rats exposed to excessive microwaves always maintained a compensation of physiologic condition up to 60-70% of the lethal time. After 75% of the lethal time, the rats went into fatal respiratory and cardiac distress. Brain temperature was very dependable for the prediction of the lethal point in time. Postmortem rat autopsies showed distinct damage to the colon at sites of low vascularization, and at sites where serous fluid was found outside the colon. In longevity studies using multiple exposures at 35-46 mW/cm², the lifespan of exposed rats was 48% of controls. At 82 mW/cm², the lifespan was only 20% of the control rats. It is thus important that longevity studies be made on radar workers and on persons in the vicinity of radar. No human personnel should be exposed to more than .01 W/cm² over short periods or over .0035 W/cm² over long periods of time. These dosages are permissible but not safe. The performance of a miniature radar dosimeter, an electromagnetic flow meter, a transistorized cardiac output meter, and other inventions is evaluated. (28 references)

- 0142 BIOLOGICAL EFFECTS OF MICROWAVE RADIATION. (E.) McRee, D. I. (Natl. Inst. Environ. Hlth. Sci., Res. Triangle Park, N.C.). *J Air Pollution Control Assoc* 24(2):122-127, 1974.

The biological effects of microwave radiation are usually designated as thermal or nonthermal (specific). Thermal effects are those interactions caused by heating of the biological specimen. Nonthermal effects are due to the direct interaction of the electromagnetic field of the incoming microwave radiation and the biological specimen. The testicles and eyes are particularly sensitive to the thermal effects of microwaves at 150-10,000 MHz. In dogs, rabbits, and rats, a power density of 10 mW/cm² is the threshold for testicular damage for indefinite exposure. The pathological damage to the testes in these animals includes degeneration of the epithelium lining of the seminiferous tubules and a sharp reduction in the number of maturing spermatocytes. The reduction in testicular function appears to be temporary and reversible. In rabbits the threshold

for cataract formation is approximately 100 mW/cm² for continuous wave radiation. Eye cataracts in man due to microwave exposure have been reported at the same power density. Threshold levels for pulsed radiation have not been adequately established. Nonthermal effects, caused by low-level microwave radiation, are most often neurological. Effects on animals include changes in EEG patterns, changes in conditioned reflexes, alterations in biocurrents of the cerebral cortex, and changes in behavior. Many subjective symptoms in exposed workers have been reported by investigators in the USSR and Eastern Europe. Genetic effects produced by microwave fields include abnormal development of chick embryos and "mealworm" beetle pupae. These effects were apparently caused by inhibition of growth and cell differentiation. In man a higher incidence of Down's syndrome has been reported in children whose fathers had prior occupational exposure to radar. Determination of the safe level of microwave exposure for the general population will require adequate measurements of the exposure and dosimetric parameters. Mechanisms of interaction of microwave radiation and the biological system must also be determined. (30 references)

- 0143 ANECHOIC CHAMBER DESIGN FOR PRECISION HIGH POWER MEASUREMENTS. (E.) Brownell, F. P. (Emerson Electr. Co., Calabasas, Calif.) and D. McCutchan. *Proc Microwave Power Symp*, May 29-31, 1974, p A1/51-A1/56.

Anechoic chambers are used to create low reflection laboratory environments approximating free space. For precision measurements involving high power microwave testing, control of reflections in the test region (or the quiet zone) is required. A straightforward design procedure has been developed during production and testing of over 300 rectangular and tapered chambers in the United States. Performance of completed chambers is evaluated by probing the quiet zone using the "Free-Space VSWR" technique. (No references)

- 0144 CHANGES IN THE PERIPHERAL BLOOD OF THE RAT EXPOSED TO MICROWAVE RADIATION (2400 MHz) IN CONDITIONS OF CHRONIC EXPOSURE. (E.) Djordjevic, Z. (Inst. Aviat. Med., Beograd, Yugoslavia) and A. Kola. *Aerosp Med* 44(9):1051-1054, 1973.

Changes in peripheral blood and some biological parameters were investigated in male Wistar rats chronically exposed (2 hr/day for 10-30 days) to microwave frequency of 2400 MHz and to power density of 10 mW/cm². Rectal temperature increased about 1 C during the first 30 min of exposure, then remained stable for the remainder of the 2-hr exposure. In contrast, a high increase (about 6 C) was recorded in animals exposed to 50 mW/cm² for up to 20 min. Hematocrit and hemoglobin values tended to increase during the first phase of irradiation at 10 mW/cm² with a subsequent return to normal values. Eosinophils decreased during the first 20 days of exposure, then increased during the later phase of irradiation. Erythrocytes increased steadily during all phases of exposure. Ophthalmologic investigations showed no significant changes in

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eye transparent coats and eye fundus in animals exposed to 10 mW/cm² for up to 30 days. Results of a survival test at a simulated altitude of 11500 m, conducted after microwave irradiation, showed no significant differences in survival times between chronically exposed animals and controls. Survival of rats exposed to 50 mW/cm² for 20 min was significantly shorter. These findings suggest an adaptive reaction to microwave radiation at 10 mW/cm² and demonstrate that this power density does not cause cataracts in rats or affect resistance to hypoxic stress. (14 references)

- 0145 MUSCLE HEATING PRODUCED IN HOG SPECIMENS BY MICROWAVES AT 915 AND 433.92 MHZ. (E.) Lehmann, J. F. (Dept. Rehabil. Med., U. Washington, Seattle), J. Stonebridge, G. Warren and B. J. DeLateur. *Arch Phys Med Rehabil* 55(5):213-217, 1974.

A round field microwave applicator operating at 433.92 MHz and a direct contact applicator, with a cooling plate, operating at 915 MHz were compared with respect to their effectiveness in heating hog musculature. The heating on skin surface and in superficial tissue was less with the direct contact applicator due to the cooling plate. The average maximum temperature change produced with the 9.5 MHz applicator was 10.7 C at an average depth of 0.80 cm in muscle and at 433.92 MHz it was 11.4 C at a depth of 0.70 cm. While the round field applicator had the better depth of penetration (3.9 cm vs 2.9 cm), there was no practical difference in effective muscle heating with the two applicators. The effective depth of muscle heating was 2.9 cm with the 915 MHz applicator and 2.8 cm at 433.92 MHz. It is noted that 915 MHz is an approved frequency in diathermy units in the United States whereas 433.92 MHz is not. (9 references)

- 0146 EXPOSURE OF *Gallus domesticus* TO VARIOUS ELECTROMAGNETIC FIELDS. (E.) Giarola, A. J. (Dept. Electr. Eng., Texas A&M U., College Station), W. F. Kreuger, R. C. Fanguy, and A. Shrekenhamer. *Proc Microwave Power Symp*, May 29-31, 1974, p B2-3/1-B2-3/7.

Egg production of *Gallus domesticus* hens was reduced 3.0-33.7% from continuous exposure to continuous wave low-level electromagnetic fields at 2.435 GHz and 915 Mhz, and to electric magnetic fields at 60 Hz. Fertility and hatchability of exposed birds were not significantly reduced when compared with controls. No macroscopic abnormalities attributable to treatments were noted in hatched chicks or in dead embryos. Hens exposed to fields at 2.43 GHz may produce eggs with poorer shell quality, as measured by specific gravity of the egg. (1 reference)

- 0147 OVICIDAL EFFECTS OF ELECTROMAGNETIC ENERGY AT 2.45 GHZ ON EGGS *Diabrotica undecim-punctata howardi* Barber. (E.) Fanslow, G. E. (Dept. Electr. Eng., Iowa State U., Ames), J. J. Tollefson, and J. C. Owens. *Proc Microwave Power Symp*, May 29-31, 1974, p B2-1/1-B2-1/4.

Eggs of southern corn rootworm, (*Diabrotica undecim-punctata howardi* Barber) were exposed to electromagnetic energy at 2.45 GHz in slotted waveguide applicators to determine ovicidal threshold levels. Ovicidal levels at transmitted power levels of 250-2000 W and exposure time up to 8 sec are presented. Infrared measurements of temperature changes (e.g., 60 C at 1 kW, 0.8 sec pulse) and estimates of the heating produced at the microwave levels used, suggest that the ovicidal mechanism is primarily thermal. (No references)

- 0148 POSSIBLE MECHANISMS FOR THE BIOMOLECULAR ABSORPTION OF MICROWAVE RADIATION WITH FUNCTIONAL IMPLICATIONS. (E.) Rabinowitz, J. (New York U. Med. Ctr., N.Y.). *IEEE Trans Microwave Theory Techn* MT21(12):850-851, 1973.

A theoretical analysis of several possible modes of molecular absorption of microwave radiation suggests that interference with some stereospecific biomolecular process may result from excitation of constrained motional states of molecular segments. Absorption of a microwave photon by the molecular segment would increase its rotational energy, leading to changes in noncovalent chemical structure but leaving the covalent molecular structure unchanged. In the interior of large molecules, the infrequency of collisions will increase the probability of multiple excitations and resultant structural changes. (5 references)

- 0149 EFFECTS OF NON-IONIZING RADIATIONS ON THE TRANSFORMING ABILITY OF *E. coli* DNA. (E.) Ranade, S. S. (Dept. Chem. Technol., U. Bombay, India), N. G. Avadhani and D. V. Rege. *Photochem Photobiol* 19(2):103-108, 1974.

A transformation system in *Escherichia coli* was used to verify the extent of the lesions caused by ultraviolet (UV) and ionizing radiations. DNA inactivated at 280 nm UV could be reactivated to some extent by exposing the transforming DNA solutions at 240 nm. Reactivation at 240 nm was dose-dependent and reached saturation at about 370 J/m². The possibility of 240 nm reactivation was demonstrated using more than one *E. coli* strain as donor, and as recipient. Transforming DNA inactivated by ionizing radiations (⁹⁰Sr beta rays and ⁶⁰Co gamma rays) was not reactivable. Low doses of beta rays (240 rad), however, reactivated the DNA inactivated by 280 nm UV to a slight but significant extent. The extent of reactivation by beta rays depended on the degree of initial 280 nm UV damage; in this respect, beta reactivation resembled 240 nm UV reactivation. It is suggested that UV and beta rays reactivate 280 nm UV damage by a parallel mechanism, i.e. de-dimerization of pyridine photo-products though at different efficiencies. (25 references)

- 0150 RESONANCE ABSORPTION OF MICROWAVES BY THE HUMAN SKULL. (E.) Joines, W. T. (Dept. Electr. Eng., Duke U., Durham, N.C.) and R. J.

Spiegel. *IEEE Trans Bio-Med Eng* BME-21(1):46-48, 1974.

A computer program was developed to calculate relative microwave absorption and distribution of electric field intensity in homogeneous and inhomogeneous (multilayered) models of the human skull. To cover a range of skull sizes, calculations were made for spheres of 7 and 10 cm radius. At frequencies in the 0.1-3 GHz range, the results for the multilayered model show pronounced resonance absorption effects that are not present in the homogeneous model. Of particular interest is a broad relative absorption peak near 2.1 GHz. Since the multilayered sphere corresponds to skin, fat, bone, dura, cerebrospinal fluid, and brain and thus represents a closer approach to reality, the leakage from microwave ovens operating at 2.45 GHz may be a greater hazard to human health than is now recognized. (9 references)

0151 THE EFFECT OF DISPERSION ON THE THERMAL CONDUCTIVITY OF DIELECTRICS CONTAINING RESONANT SCATTERING CENTRES. (E.) de Goer, A. M. (Ctr. Nuclear Studies, Grenoble, France) and L. J. Challis. *Solid State Commun* 13(7):745-748, 1973.

The effects of dispersion on the thermal conductivity of a dielectric containing randomly placed resonant scattering are considered. It is shown that dispersive effects are negligible for small concentrations of strongly coupled ions such as Cr^{2+} ions in MgO but can be important for concentrated (> 1%) systems of weakly coupled ions. (10 references)

0152 EMPIRICAL STUDIES OF CARDIAC PACEMAKER INTERFERENCE. (E.) Mitchell, J. C. (USAF Sch. Aerospace Med., Brooks Air Force Base, Texas), W. D. Hurt, W. H. Walters III, and J. K. Miller. *Aerosp Med* 45(2):189-195, 1974.

The relative susceptibility of cardiac pacemakers to electromagnetic radiation interference was tested at several representative radar sites in the U.S. The 21 pacemakers, of different types and manufacturer, were evaluated in a free-field configuration as well as in a saline solution phantom (implantation stimulation). Test results are presented for five frequency bands between 260 and 6000 MHz. Many pacemakers skipped one or two beats when the main beam of the radars scanned past the point of closest approach. This effect, observed regularly for some pacemakers at distances of a mile or more from the radars, might result in a pacemaker patient losing a normal heartbeat every 10-12 sec (about 5-6 beats/min). Although this interference is not considered a threat to life, the effect could be serious at closer distances depending on the particular pacemaker in use, the state of the patient's health, and the activity in which he is involved. (8 references)

0153 OVERVIEW OF DEPARTMENT OF DEFENSE ELECTROMAGNETIC RADIATION HAZARDS STANDARDIZATION PROGRAM. (E.) Caine, S. (Naval Electronic Systems Command, Washington, D. C.). *IEEE Int Electromagnetic Compatibility Symp*, N.Y. June 20-22, p 127-131, 1973.

High-intensity electromagnetic radiation can cause premature activation of sensitive electro-explosive devices contained in ordnance and weapons systems, ignite flammable fuel-air mixtures, cause possible biological injury to personnel, and trigger or damage solid state electronic circuitry. In 1972, the scope of the Department of Defense Electromagnetic Compatibility Standardization Program was expanded to develop criteria and documentation to preclude electromagnetic radiation hazards to weapon systems, ordnance, and military personnel. Another electromagnetic radiation hazards problem is primarily civilian and concerns electric blasting caps. These devices may be exposed to many commercial sources of electromagnetic energy, including mobile and fixed radio communications and TV transmitters, radar and navigation transmitters, geophysical survey equipment, and industrial heaters. A safety guide (ANSI C95.4-1971) approved by the American National Standards C95 Committee on Radio Frequency Radiation Hazards contains recommended distances between blasting caps and civilian transmitters. A draft of a blasting cap standard will be submitted to the committee in 6-9 months. (2 references)

0154 PRESERVATION STUDIES ON CANINE KIDNEYS RECOVERED FROM THE DEEP FROZEN STATE BY MICROWAVE THAWING. (E.) Rajotte, R. V. (MRC Transplantation Group, U. Alberta, Edmonton, Canada), J. B. Dossetor, W. A. Geoffrey Voss and C. R. Stiller. *Proc IEEE* 62(1):76-85, 1974.

Uniform heating of frozen canine kidneys (-79 to 23 ± 10 C) was achieved using a microwave heating system at 2450 MHz. The kidneys contained the cryoprotective agent dimethyl sulfoxide; uniform cooling was obtained at 1 C/min, with fluorocarbon perfusion down to -40 C. Slow environmental cooling was used from -40 to -79 C, the temperature at which the organs were stored for up to five days. After microwave thawing at 2 to 4 C/sec, temperature differences were ≤ 10 C, provided the initial kidney perfusion was complete and uniform. For comparison these microwave heating rates were also applied to organs immediately after perfusion cooling to +4 C. Microfil injection and histological studies of thawed and reimplanted kidneys have shown some preserved capillary blood vessels, but frozen-thawed kidneys have not functioned. Viability tests-oxygen and p-amino-hippurate uptake-were performed on kidney slices recovered from -79 or -196 C by the same methods. p-Amino-hippurate uptake did not survive kidney slice thawing despite the well-preserved light microscope structure of the slices. A traveling-wave thawing system may be suitable for controlled testing of human organs. (39 references)

0155 MICROWAVE OVEN TECHNIQUES FOR BIOLOGICAL SOLIDS DETERMINATION OF WASTEWATER SAMPLES. (E.) Carter, J. L. (Dept. Environ. Eng., Marquette U., Milwaukee, Wis.), D. A. Fleischfresser, and T. K. Ishii. *Proc Microwave Power Symp*, May 29-31, 1974, p A3-2/1-A3-2/4.

An industrial microwave oven was used to evaluate variables necessary to optimize the microwave drying of wastewater samples for biological solids

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Biological Effects Electromagnetic
Radiation 1(1), June 1974 and 1(2),
September 1974

determination. Comparisons were made with conventional techniques using a thermal oven at 103 C for 1 hr. The microwave oven provided comparable results in 1/4 to 1/5 of the time required by the thermal oven. The drying time required to reach a constant weight tended to decrease with increase in the operating power of the microwave oven for power settings below 1400 watts. Below 1000 watts, 15 min was required to obtain a constant weight of low-level solids samples, and the time increased with increase in amount of suspended solids on the filter. Above 1400 watts, a nearly constant time for constant weight was observed for suspended solids from 5-88 mg. At 1400 watts, 13 min was required to reach constant weight. Statistical analysis indicated that microwave dried samples reached a higher constant weight than did samples dried in the thermal oven. (2 references)

- 0156 THERMAL DENATURATION OF DNA EXPOSED TO 2450 MHz CW MICROWAVE RADIATION. (E.) Hambrick, P. E. (Natl. Inst. Environ. Hlth., Research Triangle Park, N.C.). *Radiat Res* 56:400-404, 1973.

Thermal denaturation curves of DNA formaldehyde and sodium citrate buffer solutions exposed to 2450 MHz continuous wave microwave radiation for 16 hr were compared with control curves. Both control and exposed solutions were maintained at 37 C. No differences in the curves could be detected for an absorbed power density of 94 mW/cm². In another experiment, DNA in formaldehyde solution was exposed for 1 hr at 40-50 C and therefore at higher power levels. Even with a power absorption of 225 mW/cm², there were no differences between control and exposed solutions. (19 references)

- 0157 INSECT-CONTROL STUDIES WITH MICROWAVES AND OTHER RADIOFREQUENCY ENERGY. (E.) Nelson, S. O. (U. Nebraska, Lincoln). *Bull Entomol Soc Amer* 19(3):157-163, 1973.

Control of insects infesting grain, wood, food, and other stored products can be achieved through radio-frequency (RF) dielectric heating. Such heating offers an advantage over more conventional types if the insects can be heated selectively, i.e., if they absorb energy at a higher rate than their host material and can thus be raised rapidly to lethal temperatures without damaging the host material. General principles and findings relating to insect control by RF treatment are reviewed, and the practical aspects of RF processing are discussed. Mortality and physiological injury data are presented for several stored-grain insect species. At present, immediate application of RF energy for insect control is questionable from an economic standpoint; however, cost factors could change with time and developing technology. To best exploit selective heating advantages, data on the frequency dependence and temperature dependence of the dielectric properties of insects and their host materials are needed. (41 references)

- 0158 COLOUR-THERMOGRAPHY: A POWERFUL TECHNIQUE IN THE EVALUATION OF MICROWAVE FIELD RADIATION PATTERNS IN BIOLOGICAL SYSTEMS. ITS USE

AS A MICROWAVE ENERGY DENSITY MONITOR. (E.) Bigu del Blanco, J. (Dept. Anat., Queen's U., Kingston, Canada), C. Romero Sierra and J. A. Tanner. *Proc Microwave Power Symp*, May 29-31, 1974, p A3-3/1-A3-3/4.

Infrared scanning (color-thermography) was used for power density measurements at X-band frequencies (7-10 GHz). Experiments were conducted in an anechoic chamber in the presence and absence of animals or plant vegetation. Dramatic changes in radiation patterns occurred in the presence of a biosystem and were attributed to the large disturbance introduced by the system on the imposed electromagnetic field. Color-thermography enabled simultaneous visualization of radiation patterns over large areas of interest, and made it possible to establish the diffraction and scattering properties of the specimens. In some cases, resonance absorption was observed and in all cases multipath wave formation was established. These results emphasize the limited validity of free-space power density measurements as indicators of biological and behavioral hazards of microwave radiation. (1 reference)

- 0159 MICROWAVE HEARING: EVIDENCE OF THERMOACOUSTIC STIMULATION OF THE HUMAN AUDITORY SYSTEM BY PULSED MICROWAVES. (E.) Foster, K. R. (Natl. Naval Med. Ctr., Bethesda, Md.) and E. D. Finch. *Science* 185(4147):256-258, 1974.

In water, a 2450 MHz radiation pulse at the threshold for microwave "hearing" in humans produced pressure transients of approximately 90 dB re 0.0002 dyne/cm² peak amplitude within the 200 Hz-20 KHz frequency band audible by bone conduction. This peak pressure level is adequate to explain the "clicks" heard by persons exposed to identical radiation. (12 references)

- 0160 NONIONIZING RADIATION HAZARDS. (E.) Schwan, H. P. (Moore Sch. Electr. Eng., U. Pennsylvania, Philadelphia). *J Franklin Inst* 296(6):485-497, 1973.

The physical and engineering-oriented approach to the biological effects of microwaves carried out at the Moore School for over 20 yr is largely responsible for the Western standard of 10 mW/cm². Various phases of this research include determination of the electrical characteristics of body tissues; determination of microwave and membrane characteristics; studies of a variety of electromechanical phenomena which can be evoked by radio frequency fields; investigations of the mode of propagation of microwaves into man and animals, including absorption and reflectance characteristics and radar cross-section of man. The accepted standard for safe exposure derives from the relationship between incident power and power absorbed by man, and the absence of any known dangerous nonthermal mechanism. Flux data indicate that exposure standards can be drastically relaxed below 30 or 100 MHz. (28 references)

- 0161 THE EFFECT OF MICROWAVES ON THE TOBACCO BEETLE. (E.) Laszlo, T. S. (Philip

Morris U.S.A. Res. Ctr., Richmond, Va.) and W. K. Stephens. *Proc Microwave Power Symp*, May 29-31, 1974, p B3-4/1-B3-4/5

Specimens of all four life stages of the tobacco beetle, *Lasioderma serricorne*, were embedded in cut tobacco and exposed to identical microwave treatment at 2450 MHz. Specimens were removed from the tobacco bed immediately after exposure or left in the tobacco for 2 or 16 hr. With identical exposure the death ratio increased with storage time in the still hot tobacco. The mortality is attributed entirely to thermal effects of microwaves. Theoretical considerations suggest that malformations observed by other investigators after microwave treatment are also due to heating. Microwave energy is many orders of magnitude less than chemical bond energies. Thus microwave radiation cannot break chemical bonds, and the formation of new chemical compounds from existing ones in biological systems exposed to microwaves has a very low probability. (No references)

0162 HUMAN PERCEPTION OF MODERATE STRENGTH LOW FREQUENCY MAGNETIC FIELDS. (E.) Schmitt, O. H. (Biophys. Group, U. Minnesota, Minneapolis) and R. D. Tucker. *Proc IEEE 1973 Electromagnetic Compatibility Symp*, June 1973, p 65-70.

If humans cannot perceive even subliminally that they have been immersed in or removed from a 60 Hz magnetic field of a few gauss strength, it becomes improbable that weak magnetic fields have deleterious effects. With whole body immersion in a large Helmholtz coil field, some few individuals demonstrate perception scores absolutely impossible by chance. With acoustically quiet sources and with better and better isolation from auxiliary nonmagnetic clues, fewer and fewer individuals show significant perception and none develop the very high scores found for sensitive subjects in the open coil system. Perception scores may approach negligibility with an acoustically sealed isolation cabinet now being tested. (No references)

0163 POTENTIAL INSECT CONTROL APPLICATIONS FOR MICROWAVES. (E.) Nelson, S. O. (Agric. Res. Service, U. Nebraska, Lincoln). *Proc Eur Microwave Power Symp (Belgium)*, Vol. 2, 1974, C.14.5, p 1-4.

Theoretical and experimental data on insect control by application of microwaves and lower frequency radiofrequency (RF) energy are presented. The most promising experimental results have been obtained when the energy absorption rate in the insects is high compared with that in the host material. Under these conditions, the insects can be disabled or killed by selective or differential dielectric heating. Many insects that infest grain, cereal products, and wood can be controlled by short exposures to RF fields that do not damage the host material. The resulting host temperatures necessary for insect control are 40-70, depending on the host, the insect species, the developmental stage, and the nature of the RF treatment. Studies of the frequency dependence of the dielectric properties of insects and host media suggest that better selective heating of

insects can be obtained by increasing the frequency during exposure. (11 references)

0164 MICROWAVE RADIATION. (E.) Sells, S. B. (Inst. Behavioral Res., Texas Christian U., Fort Worth), M. J. Duke, and N. Findikyan. *Stress Reviews Radiation* (Texas Christ. U., Ft. Worth), Contract Nonr 3436 (00), Aug. 1966, p 15-33.

Microwaves affect man adversely in at least four ways: by raising tissue temperature to intolerable levels and causing cellular damage or death; by emanation of x-rays from microwave equipment; by molecular absorption in tissues; and directly, as heat or in some other manner, setting off stress reactions. Variables of biological importance are frequency, wavelength, and power in watts. Much of the present radar equipment operates at frequencies that are largely reflected or absorbed in the first few millimeters of body tissue. However, microwave effects vary with the tissues affected. Vascularized tissues, provided with a blood supply, can absorb more radiation than nonvascularized tissues, such as the lens of the eye. Local tissue exposure, particularly of the eyes, may be more important in relation to microwave radiation than whole-body exposure. The calculated tolerance to whole-body exposure (.143 large cal/min, equivalent to 0.1 kW/m²) provides a large safety factor under ordinary circumstances, although allowance must be made for high air temperature, high humidity, and other conditions conducive to raising body temperature. No case of verified injury to radar personnel was found in a study of 335 persons exposed over a 14-yr period. Nevertheless, the potential hazard of new equipment should be monitored. As voltages rise, shielding becomes more difficult due to the more intense x-radiation produced, which, uncontrolled, could be more hazardous than the microwave radiation itself. (32 references)

0165 CYTOGENETICS, CHEMICAL DOSIMETRY SECTION, AND ANIMAL CARE SECTION. (E.) Eastern Environ. Radiat. Lab. (Montgomery, Ala.). *Annual Report*, Jan.-Dec. 1970, p 26-37.

One of several microwave radiation projects was a study of the cytogenetic effects of 2450 MHz radiation on kidney, lung, and thyroid tissue of Chinese hamsters given a 2-min exposure at a power density of 200 mW/cm². Preliminary results from cultured cells indicate a significantly higher percentage of aberrations in irradiated hamsters (6-10%) than in controls (1%). Temperature rises measured in samples of distilled water and agar solution irradiated in a microwave oven (frequency 2450 MHz) showed that placement of the sample to be exposed is critical for relatively consistent exposures in chemical dosimetry studies. Experiments conducted in a calibrated microwave radiation facility showed no direct functional relation between optical rotation changes in a sucrose-polyvinylpyrrolidone-glycerin mixture and absorbed microwave energy. In other experiments, enzymes (sucrase, peroxidase, aldolase, alpha amylase, alcohol dehydrogenase, and catalase) were exposed to high power density levels in a microwave oven and to lower

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power density levels (200 mW/cm²) in an anechoic chamber. Comparison with enzymes heated in an oil bath provided no indication that the enzymes studied are sensitive to microwave radiation. Microwave radiation did not affect the viscosity of several polymers tested nor the stability of 2-diphenyl-1-picryl-hydrazyl. The Chinese hamster colony for experimental studies has increased to approximately 4000 animals. (4 references)

0166 POLAROID MICROWAVE LEAKAGE MEASUREMENT, HAZARD EVALUATION OF MARINE RADAR ON PLEASURE CRAFT, FLUORESCENT LIGHT BULBS AS MICROWAVE OVEN INTERLOCKS, PRODUCT TESTING. (E.) Eastern Environmental Radiation Laboratory (Montgomery, Alabama). *Annual Report*, Jan.-Dec. 1970, p 49-52.

An investigation of the use of Polaroid film for measurement of leakage radiation from microwave ovens confirmed that Polaroid Type 58 color film provides visual indication of microwave fields with power densities greater than 5 mW/cm², the value set by PL 90-602 for microwave ovens following purchase by the consumer. Localized heating resulting from microwave exposure at 5 cm from the oven door caused a selective increase in film development rate in these areas. This increase resulted in a darkening of the film in the heated areas and formation of an image corresponding to the intensity of the electromagnetic field. Theoretical power density calculations for marine radar units used on small pleasure craft indicated that average power densities in excess of 10 mW/cm² may exist near the antenna (the current USASI standard for exposure times > 6 min). The feasibility of using fluorescent light bulbs as microwave oven interlocks was also investigated, using the property of the bulbs' ignition in a microwave field. Results show that the bulbs do not have a uniform ignition level and would require critical individual spacing to ignite at a pre-determined leakage level. In support of a national survey, approximately 200 microwave oven owners in Alabama, Georgia, Texas and Tennessee were surveyed. Owners of ovens leaking slightly above the industry design standard of 10 mW/cm were advised to discontinue use of their ovens pending repair. (No references)

0167 MICROWAVE RADIATION. (E.) Roth, E. M. (Lovelace Fdn., Albuquerque, N.M.). *Compendium Human Responses Aerospace Environment*, Vol. 1, Sect. 1-6, 1968, p 1/1-1/26.

Microwave penetration of tissue is discussed as a function of frequency (100-30,000 MHz). Thermal factors in microwave absorption are reviewed together with available data on microthermal and non-thermal effects. Total body, nervous system, ocular, and testicular effects of microwaves have been observed in animals. Dogs continuously exposed to 3000 MHz develop cataracts if the eye temperature reaches at least 45 C, but much lower temperature elevations in excess of 1 C are associated with testicular damage. These represent animal data most pertinent to man. U.S. and Soviet retrospective studies of radar workers are reviewed, and U.S. and

Soviet limits of safe exposure are compared. A value of 0.01 watt/cm² absorbed energy appears tolerable for long-time total body exposure and 0.1 watt hr/cm² tolerable for short exposures. Possible tolerance levels for specific frequencies are 0.03 watt/cm for below 500 MHz, 0.01 watt/cm² for 1000-3000 MHz, and 0.2 watt/cm for frequencies in excess of 3000 MHz. The potential value of the microwave cross-section of man in operations such as search and rescue is noted. Animal data on the synergism between microwave and ionizing radiation are briefly summarized. (85 references)

0168 MICROWAVE REFLECTION, DIFFRACTION AND TRANSMISSION BY MAN: A PILOT STUDY. (E.) Reno, V. R. (Naval Aerospace Med. Res. Lab., Pensacola, Fla.) and D. E. Beischer. *Naval Aerospace Med Res Lab Report No. 1183*, June 11, 1973, 9p.

The microwave energy reflected, diffracted, and transmitted by man was measured as part of an ongoing investigation of the biological effects of low intensity microwave radiation on man. Energy density patterns were determined in proximity to human participants introduced into horizontally or vertically polarized microwave fields of low intensity (<50 μ W/cm²) at 1 GHz. In both cases the radiation formed a standing wave in space on the illuminated side and a pronounced shadow on the opposite side. Differences in interference patterns were related to polarization of the incident wave. The most apparent of these occurred in the diffraction patterns seen in the shadow areas. These observations place restrictions on the proximity of several subjects exposed at the same time to a microwave field for observations of biological effects. Similar considerations extend to the location of experimental apparatus adjacent to the subject. (3 references)

0169 USE OF MICROWAVE AND LOWER FREQUENCY RF ENERGY FOR IMPROVING ALFALFA SEED GERMINATION. (E.) Nelson, S. O. (U.S. Dept. Agric., U. Nebraska, Lincoln) and L. E. Stetson. *Proc Microwave Power Symp (Wis)*, May 29-31, 1974, p PS 1-1/2 to PS 1-1/4.

Brief exposures of samples from many different alfalfa seed lots to 39 MHz electric fields consistently increased germination by decreasing the percentage of hard seeds. Comparison tests on fewer seed lots showed no real differences between the effectiveness of treatments at 5, 10 and 39 MHz, or between treatments at 39 MHz and treatments at 2450 MHz in the microwave range. Germination of most seed lots was increased from the 40-60% range to the 80-90% range by radiofrequency treatment. Effectiveness of treatment in lowering hard-seed content increased with decreasing moisture content. (No references)

0170 MICROWAVE REFLECTION, DIFFRACTION AND TRANSMISSION STUDIES IN MAN. (E.) Reno, V. R. (Naval Aerospace Med. Res. Lab., Pensacola, Fla.). *Naval Aerospace Med Res Lab Report No. 1199*, Feb. 1974, 42p.

A series of studies of the energy distribution in proximity to man during microwave illumination is in

progress. The studies indicate several concepts of importance for investigations of the bioeffects of nonionizing radiation. A pronounced diffraction field is generated in space in proximity to man during illumination by microwave energy at 1 or 4 GHz (maximum intensity of incident field at either frequency, approximately 0.7 nJ/m^3). The characteristics of the field are dependent on the complex relationships between the frequency and polarization of the radiation and geometry and dielectric properties of man. Definite standing waves are formed on the illuminated side of man and pronounced areas of shadow appear on the opposite side. Considerable energy is also present in the field alongside man, if the electric vector of the incidence wave is parallel to the long axis of man. If the wave is polarized horizontally relative to man, this energy is redistributed so the amount present at the lateral aspects is much reduced. A considerable amount of the energy incident on man was reflected under all conditions tested. The information obtained is immediately applicable to hazard evaluations and the design of bioeffect investigations. A significant benefit of the approach is the potential for development of a noninvasive method for estimating the energy absorbed by man from a microwave field. (15 references)

- 0171 INSECT-CONTROL POSSIBILITIES USING
MICROWAVES AND LOWER FREQUENCY RF ENERGY.
(E.) Nelson, S. O. 1974 IEEE S-MTT Int Microwave
Symp Digest Technical Papers (Ga), June 12-14,
1974, p 27-29.

Principles applicable to controlling stored-product insects with radiofrequency (RF) energy and general findings of research on this topic are reviewed. Many insects infesting grain, cereal products, and wood products can be controlled by short exposures to RF fields without damage to the host material. Resulting temperatures in the host material necessary for insect control are generally between 40-70 C, depending on the host, the insect species, and the nature of the RF treatment. Differences have also been found in the susceptibility of different development stages within the same species. Data on the frequency dependence of the dielectric constant and dielectric loss factor of insects and grain indicate that efficiency of RF treatment can be improved by increasing the frequency during exposure to more nearly follow the maximum insect-to-grain loss factor ratio as the treatment progresses. With improvement of efficiency, RF insect-control methods may become economically practical. (9 references)

- 0172 DIELECTRIC PROPERTIES OF AGRICULTURAL
PRODUCTS. (E.) Nelson, S. O. (U.S. Dept.
Agric., U. Nebraska, Lincoln). Proc 1973 Micro-
wave Power Symp (England), Sept. 11-13, 1973,
p 6B1 to 6B1/2.

The dielectric properties of materials are important in understanding the interaction of electromagnetic energy and materials. Considering agricultural products, possible uses for microwave and lower frequency radio frequency energy include both high and

low-power applications. High-power uses might include heating, drying, sterilization, or insect control processes. Low-power applications include measurement or monitoring processes and noncontacting or nondestructive testing for quality measurement or control. Dielectric properties of agricultural materials vary widely and are dependent on many factors, including frequency, temperature, moisture content, and density. (No references)

- 0173 INTERACTION OF MICROWAVE AND RF ENERGY
ON BIOLOGICAL MATERIAL. (E.) Sher,
L. D. (Moore Sch. Electr. Eng., U. Pennsylvania,
Philadelphia). Electronic Product Radiation and
the Health Physicist, Oct. 1970, p 432-461,
NTIS: PB-195 772.

Microwave hazards are greater under near field than far field radiation conditions. Unlike the far field, the near field has a complex radiation pattern that is closely dependent on the nature of the radiating source and its immediate environment. The extent of the near field is proportional to the directivity of the source. An electric field and a magnetic field coexist in the propagating microwave radiation. Magnetic interactions with biological material are very weak, but the electric field can lead to a marked heat development in biological tissue. Theoretical and model-system studies indicate that a man absorbs all radiation incident on his geometric cross section. His capacity for self-protection is limited to frequencies (above 10,000 MHz) at which the thermal input is sensed via cutaneous thermal receptors. Because currently available dosimetry is ineffective in the near field, it has not been possible to determine significant effects on tissues of microwave heating at levels considered to be safe. Protection from undue thermal effects, as offered by the U.S. Radiation Protection Guide, insures automatic protection against any possible nonthermal effects whose biological significance is unknown. Mechanisms for nonthermal effects other than field-induced force effects have not been demonstrated. (No references)

- 0174 ACETYLCHOLINE AND CHOLINE LEVELS IN THE
RAT CORPUS STRIATUM AFTER MICROWAVE IRRADIATION. (E.) Butcher, S. G. (U. California Sch. Med., Los Angeles) and L. L. Butcher. Proc West Pharmacol Soc 17:37-39, 1974.

A comparison was made between levels of acetylcholine (ACh) and choline (Ch) in Sprague-Dawley rat striata after decapitation and after rapid enzyme inactivation by a microwave fixation system. In the 3-min interval between decapitation and brain dissection, ACh levels decreased by 54.4 nmoles/g and Ch levels increased by 100 nmoles/g. These rapidly occurring changes were prevented by microwave irradiation at 6000 J (5kW for 1.2 sec). Parallel histochemical experiments showed virtually complete loss of acetylcholinesterase and NADH-diaphorase activities in the caudate-putamen nucleus after irradiation. (5 references)

CURRENT LITERATURE

- 0175 RADIATION HAZARDS FROM THERAPEUTIC
MICROWAVE DIATHERMY. (E.) Vawter, S. M.
(Am. Med. Assoc., Chicago, Ill.). *JAMA* 228(9):1170,
1974.

Microwave diathermy at 900 or 2450 MHz is similar to the radiation produced by microwave ovens. Because the primary effect of microwaves on the body is to produce heat, an overdose could result in a burn, internally or externally. The temperature increase in the body due to microwave exposure depends on (1) the specific area exposed and the efficiency of heat elimination from that area, (2) the intensity of the microwave field, (3) duration of exposure, (4) wavelength, and (5) thickness of skin and subcutaneous tissue. The lens of the eye is considered the organ most sensitive to microwave exposure, and cataracts may be produced at levels above 100 mW/cm². Data on long-term, low-level exposure to the lens are inadequate to determine if a cumulative effect exists. (2 references).

- 0176 ANALYSIS OF CENTRAL NERVOUS SYSTEM
INVOLVEMENT IN THE MICROWAVE AUDITORY
EFFECT. (E.) Taylor, E. M. (U. Washington Sch.
Med., Seattle) and B. T. Ashleman. *Brain Res*
74(2):201-208, 1974.

Nine cats were prepared for the recording of potentials in three brain sites evoked by acoustic stimuli (square wave pulses 10 μ sec in duration with a repetition rate of 1 pulse/sec) and microwave stimuli (pulses of 2450 MHz energy). Loci in which potentials were observed were the eighth cranial nerve, medial geniculate nucleus, and primary auditory cortex. The effect of cochlear disableness on these potentials was evaluated. Potentials at all sites were abolished by cochlear damage. There were no differences between acoustic and microwave stimuli in this regard. The data support the contention that the microwave auditory effect is mediated at the periphery as are the effects of conventional acoustic stimuli. (9 references)

- 0177 PSYCHOPHYSIOLOGICAL EFFECTS OF EXTREMELY
LOW FREQUENCY ELECTROMAGNETIC FIELDS:
A REVIEW. (E.) Persinger, M. A. (Dept. Psychol.,
Laurentia U., Sudbury, Canada), H. W. Ludwig, and
K.-P. Ossenkopp. *Perceptual Motor Skills* 36:1131-
1159, 1973.

Extremely low-frequency (ELF) electromagnetic field waves, defined as occupying the frequency band from .01-100 Hz, are associated with geomagnetic disturbances, weather perturbations, electrical appliance discharges, and possibly seismic movements. ELF electromagnetic phenomena have been recorded as sinusoidal-like wave forms or as ELF pulses of short duration from higher frequency waves (10-100 kHz). Although natural ELF electrical component intensities range from less than 1 mV/m to slightly more than 1 V/m with magnetic components less than a μ gauss and calculated power densities of 10⁻⁸ watts/m², these waves can pro-

pagate long distances without appreciable attenuation and penetrate housing structures. Theoretical calculations show that energy available from ELF phenomena can contribute to neuro-energetic functioning and protein-lipid activity. Correlational and experimental data indicate that ELF fields can influence reaction time, timing behavior, ambulatory behavior, oxygen uptake, endocrine changes, cardiovascular functions, and precipitation-clotting times of colloids. Possible mechanisms of ELF-organismic interactions are discussed. Correlational studies between ELF and life processes could be helpful as sources of stimulation for experimental design. This can be accomplished by increasing the number of stations measuring ELF waves and very low-frequency (3-30 kHz) carriers on a national and international scale. (136 references)

- 0178 FINAL ENGINEERING REPORT: RF RADIATION
HAZARD DETECTION AND WARNING DEVICES:
PHASE I AND II. (E.) Bissett-Berman Corp., Santa
Monica, Calif. *Bureau of Ships Report* Contract No.
N0bsr 87467, Project No. SF 013 01 017, June 30,
1964, 80p NTIS: AD604900

Recognition that physiological damage caused by microwave radiation is a function of exposure time as well as power density level required the development of a radiofrequency (RF) radiation integrator. Two integrating power density meters have been developed for protecting personnel against high-power radar and other electromagnetic radiation emitting systems. The first instrument accumulates incident electromagnetic energy over a 30-sec interval and reads out the total value on a counter. The second instrument is a portable, battery-operated RF integration detector which accumulates incident electromagnetic energy of a 30-sec interval and actuates first, second, or third level visible and audible alarms when total energies exceed 0.3, 0.6, and 3.0 J/cm², resp. Both instruments utilize the E-CELL as the integrating device; in this new electrolytic component, transfer of a platable material between electrodes is proportional to the incident energy. The 30-sec integration period conforms to current Bureau of Ships requirements and can be changed to accommodate integration periods of from 1 sec to many hr. The E-CELL integration technique offers other instrumentation possibilities: a lower cost RF radiation integrator which would read out and alarm only when a hazardous condition exists; the integration of ionizing radiation for a personal alarm dosimeter; and the integration of various inputs such as solar intensity, wind, current velocity, or the operational hours of electronic devices. (No references)

CURRENT RESEARCH

SOURCES: Smithsonian Science Information Exchange

- 0001 BIOPSYCHOLOGICAL STUDIES OF MICROWAVE IRRADIATION. Justesen, D. R.; Levinson, D. M. (U. Kansas Sch. Med., Kansas City, Kansas 66101).

Sensory thresholds of response to microwave energy will be assessed in animals. Rats, guinea pigs and squirrel monkeys will be exposed, in multi-mode cavities, to microwave energy at 915 and 2450 MHz. During exposure, the animals will be observed to determine the effect of carrier frequency modulation on sensory thresholds and to evaluate the gross anatomical locus of detection. Following selected irradiation experiments (duration and power density variables) on fetuses, infants and adults, examinations will be made on adult animals for (1) learning ability and retention of simple and complex tasks, and (2) visually-evoked, and electrocortical responses. Ancillary studies will evaluate the interaction between endogenously triggered hyperthermia, which is produced by "psychological" stress, and irradiation. (6/73-5/74)

SUPPORTING AGENCY: HEW, Publ. Hlth. Serv., FDA, Bur. Radiol. Hlth.

- 0002 EPIDEMIOLOGICAL FIELD STUDY OF ATHERMAL NONIONIZING EXTREMELY LOW FREQUENCY (ELF) ELECTROMAGNETIC RADIATION EFFECTS. Krumpe, P. E. (U.S. Navy, Med. Res. Unit. #4, Waukegan, Illinois 60088).

The object of this study is to provide complete accurate clinical and epidemiological base lines on the health of technicians exposed to ELF radiation at Sanguine Test Facility, Clam Lake, Wisconsin. The health status of Sanguine "test subjects" who continue to be exposed to ELF radiation will be evaluated by complete annual examinations. Any changes in the health status of these subjects will be recorded in the form of a "problem oriented" medical record. (7/72-6/73)

SUPPORTING AGENCY: Department of Defense, Naval Med. Res. Inst.

- 0003 PERSONNEL EXPOSURE CRITERIA FOR OPERATIONAL RADIOFREQUENCY RADIATION ENVIRONMENTS. Bonney, C. H. (USAF Sch. Aerospace Med., San Antonio, Texas 78235).

An attempt will be made to establish appropriate exposure criteria for operational radiofrequency radiation environments. Current exposure guidelines do not apply to many operational situations. Data are needed for site selection and layout, shielding requirements and operational maintenance procedures for such systems as the over-the-horizon (OTH) radar for conus defense. A series of exploratory tests will be conducted to establish power absorption/energy deposition parameters as a

function of frequency, field intensity, sample configuration, and environmental stress. Initial studies will be conducted in the HF range at 10.5, 19.27 or 26.6 MHz with 50 KWP pulse transmitter. These studies will include measurement of resulting temperature changes in representative boundary interface models and evaluation of the RF radiation-induced effect on the growth rate in mice. Subsequent studies will be conducted using the new 40 KW (An/FRT-6B) continuous wave transmitter. Results will be used as a biomedical data base for the establishment of normal and emergency exposure limits for specific operational situations. (7/72-6/73)

SUPPORTING AGENCY: Department of Defense, USAF Sch. Aerospace Med.

- 0004 EFFECTS OF HF BAND ELECTROMAGNETIC FIELDS ON THE CENTRAL NERVOUS SYSTEM: PERMISSIBLE EXPOSURE CRITERIA. Stavinoha, W. B. (U. Texas Sch. Med., Pharm., San Antonio, Texas 78229).

The effects of electromagnetic fields on the turnover rates and energy metabolism of neurotransmitter substances will be studied. While present safety criteria for nonionizing radiation are based on thermal effects studies of varying frequencies (300-300,000 MHz), thermal effects information is limited for lower Air Force frequencies. In addition, energy transfer mechanisms and their possible long term effects require definition and evaluation. Data acquired will be used to establish human exposure criteria and contribute to the establishment of hazard levels in RF fields. Methods for 100 mg tissue sample assay of neurotransmitter (acetylcholine, deoxyphenylalanine, gamma-amino butyrate) have been perfected and calibrated. Brain tissue (cortex and hypothalamus) from animals exposed to 3 HF fields at 3 power levels will be examined for neurotransmitter turnover rates. Labeled precursors and new rapid enzyme inactivation techniques will be used. The turnover of major energy stores will be determined for adenosine triphosphate (ATP), diphosphate (ADP) and monophosphate (AMP). The structurally determined sequences in mitochondria will also be studied. (7/72-6/73)

SUPPORTING AGENCY: Department of Defense, USAF Sch. Aerospace Med. Res.

- 0005 EFFECTS OF LOW FREQUENCY ALTERNATING CURRENT FIELDS ON BIOLOGICAL SYSTEMS. Straub, K. D. (U.S. Navy, Crew Systems Department, Warminster, Pa. 18974).

The effects of low frequency alternating current (1 Hz - 10 KHz) on various well defined cellular parameters will be determined in order to provide a

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Biological Effects Electromagnetic
Radiation I(1), June 1974 and I(2),
September 1974

basis for the estimation of the possible effects of these low frequency fields on personnel and the environment, particularly the fields generated by Project Sanguine, Omega and very low frequency (VLF) communication and navigation transmitters. Various well-defined cellular and tissue preparations will be subjected to a.c. fields of varying frequency and strength. Parameters such as ionic potential, oxygen consumption, metabolic levels and enzyme activity will be monitored and the effects of a.c. fields determined on the basis of changes in these parameters. These effects can then be used to design experiments which involve exposure of the whole body.

SUPPORTING AGENCY: Department of Defense, Naval Bur. Med. Surg.

0006 PERFORMANCE IN NON-HUMAN PRIMATES AS INFLUENCED BY LOW FREQUENCY ELECTROMAGNETIC FIELDS. Delorge, J. O.; Grissett, J. D. (U.S. Navy, Aerospace Med. Res. Lab., Pensacola, Florida 32512).

The influence of low intensity, low frequency electromagnetic fields on *Macaca mulatta* will be analyzed for possible relevance to human behavior under similar influences. In addition, the possible function of fields as stimuli for arousal will be investigated. Specific tasks, found to produce behavioral sensitivities to electromagnetic fields in humans and animals, will be taught to rhesus monkeys through the use of operant conditioning techniques. Presented successively, the tasks assess an organism's reaction to temporal stimuli, auditory signal, and the immediate memory of visual stimuli. When a consistent performance of the three tasks has been established, the monkey will be subjected to an extremely low frequency (ELF) electric field and further data collected. The field will later be removed and the original conditions reinstituted to observe the behavioral recovery of the animal to pre-exposure levels. A similar procedure will be followed with an ELF, low-intensity magnetic field and a combined electric and magnetic field utilizing the same exposure values. The second phase of the experiment will focus on the reaction time task as an indication of electromagnetic field stimuli. Results will be applied to behavioral research in ELF communication systems. (7/72-6/73)

SUPPORTING AGENCY: Department of Defense, Naval Aerospace Med. Res. Inst.

0007 PARENTAL RADIATION EXPOSURE AND DOWN'S SYNDROME, WITH PARTICULAR ATTENTION TO IONIZING RADIATION AND RADAR. Cohen, B. (Johns Hopkins U. Sch. Med., Baltimore, Maryland 21205).

This project proposes to study the genetic and chromosomal effects of microwave radiation specifically in relation to Down's syndrome (mongolism). This project is in direct support of the project to define the military medical problems associated with exposure to microwave hazards and is relevant to

the mission of the Army medical department in maintaining military forces in the field. Children with a diagnosis of Down's syndrome will be selected. Medical records of parents will be examined and the parents interviewed. Particular emphasis will be placed on previous history of radiation exposure to determine if any aberrations in chromosomes are noted. Differences between controls and experimental subjects will be examined for any discernible differences and/or abnormalities. (7/72-6/73)

SUPPORTING AGENCY: Department of Defense, Army Med. Res. & Develop., Internal Med. Res. Div.

0008 QUANTITATIVE EFFECTS OF EM ENERGY ON HUMAN TISSUES. Guy, A. W.; Lehmann, J. F.; Lin, J. C.; Taylor, E. M. (U. Washington Sch. Med., Seattle Washington 98105).

The biological effects of electromagnetic energy will be quantifiably assessed. Engineering studies involving theoretical prediction and experimental verification of energy distribution as a function of exposure parameters in phantom models and animal tissue, will be applied to the evaluation of biological effects data and the design of relevant experiments. In particular, evaluation of energy distribution around diathermy and optimization of designs for the safety of the patient and operator will take place. Present low level thermal effects of EM radiation on CNS-evoked responses will be expanded to include investigation of somatic and autonomic consequences. Blood pressure, heart rate, respiration and other bodily functions will be monitored during exposure. Techniques of recording and sequential system ablation will be employed in the observation of auditory response to pulsed electromagnetic energy. Cat spinal cord preparations will be used in detailing EM energy effects in discrete aggregates of CNS elements. The vagus nerve of the cat will be differentially radiated in a chronic preparation and effects on heart rate and blood pressure noted. For the assessment of conduction and junction phenomena in terms of absorbed energy, amphibian and mammalian peripheral nerves and neuromuscular junctions will be illuminated in temperature controlled chambers. Single cells from rabbit dorsal root ganglia will also be illuminated with EM energy during intracellular potential recording to assess single element effects. Biological and engineering data will be extrapolated to the human exposure problem (6/73-5/74)

SUPPORTING AGENCY: HEW, Publ. Hlth. Serv., FDA, Bur. Radiol. Hlth.

0009 VISION HAZARDS TO AIRCREW PERFORMANCE. Welch, A. J. (U. Texas Sch. Engineer., Austin, Texas 78712).

Successful performance of aircrew duties requires detail vision. Accidental photocoagulation of small areas of the retina may degrade work quality and

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result in loss of life or loss of USAF equipment. Minimum changes in vision which alter job performance must be determined for safety of personnel working with high energy density light sources. These threshold determinations must be obtained using standard medical and optometric tests, and related to electrophysiological changes. Since permanent eye damage is a distinct possibility, and experimental surgical preparation is necessary, rhesus monkeys must be used as subjects. The data will be extrapolated to human vision conditions. First, surgical preparation of six rhesus monkeys will be accomplished to obtain baseline vision-related electrical activity of the brain recordings. Photo evoked potentials will be obtained under baseline conditions as well as a measure of vision capability using standard clinical optometric tests of detail vision. Second, lesions will be placed in the fovea varying spot size, and a corresponding visual field defect 'map' will be obtained. Third, visual acuity will be obtained to determine functional vision capability changes from baseline conditions. Data will be reported for the energy source, density, duration, and wavelength, which altered electrophysiological and functional vision changes. (7/72-6/73)

SUPPORTING AGENCY: Department of Defense, USAF Sch. Aerospace Med.

0010 HISTOPATHOLOGICAL EXAMINATIONS OF EYES EXPOSED TO VARIOUS WAVELENGTH ELECTROMAGNETIC RADIATIONS. Vassiliadis, A. (Stanford Res. Inst., Menlo Park, California 94025).

Studies are underway to determine the medical effects of electromagnetic and particulate radiation. Exposures to AF operational radar frequencies, lasers and nuclear weapons environments will be studied. Findings will be used to establish medical safety criteria for hazard assessment of AF operational system/environments. This effort will provide detailed histopathological examination of about 150 primate eyes. Changes in both retina and lens will be precisely located, evaluated and interpreted. Animals will be exposed to various radiations. At prescribed times, enucleations will be performed and the eyes sent for histopathological examinations. Information from the examinations will be correlated with other data to produce exposure criteria necessary for utilization of aerospace environments contaminated with radiation. (7/72-6/73).

SUPPORTING AGENCY: Department of Defense, USAF Sch. Aerospace Med.

0011 ANALYSIS AND PREPARATION OF THE AVAILABLE WORLD LITERATURE ON THE BIOLOGICAL EFFECTS OF NONIONIZING ELECTROMAGNETIC RADIATION. Lindberg, R. (Mead Technology Laboratories, Dayton, Ohio 45432).

Selected literature on the biological effects of non-

ionizing electromagnetic radiation will be entered into a computerized file in full text and in a manner to provide rapid review and retrieval. (7/73-6/74)

SUPPORTING AGENCY: Department of Defense, Army Med. Res. & Develop.

0012 NAVY ENVIRONMENT: NON-THERMAL HAZARDS OF EXPOSURE TO RADIO FREQUENCY AND MICROWAVE FIELDS. Mickey, G. H. (New England Institute Inc., Ridgefield, Conn. 06877).

The possibility exists that shipboard radar exposure may induce genetic damage in naval personnel. This research project explores the incidence of genetic anomalies after exposure to radar frequency microwaves. Microwave treatments in the X and K bands at 15 to 40 MHz are administered to Chinese hamster cells *in vitro* (lymphocytes and lung cells in culture) and to whole Chinese hamsters for subsequent removal and study of bone marrow cells, lymphocytes, and germ cells, using double blind coded preparations. The total number of chromosome breaks are scored and compared with chromosome breaks in controls, and a dose-response curve constructed. In another approach, genetic effects of microwaves on germ cells of male rats will be determined. Pregnant female rats which have been mated with microwave irradiated males will be autopsied on the 14th day of pregnancy and scored as to incidence of early fetal and pre-implantation deaths. (7/72-6/73).

SUPPORTING AGENCY: Department of Defense, Off. of Naval Res.

0013 RESEARCH INITIATION - EFFECTS OF RADIATION ON BIOLOGICAL SYSTEMS. Cain, C. A. (U. Illinois Grad. Sch., Urbana, Illinois 61801).

The purpose of this research is to determine if RF radiation can affect functioning biological systems by non-thermal mechanisms. The effects of pulse modulated RF energy on heart and brain function in the cat will be studied. (3/73-8/74).

SUPPORTING AGENCY: NSF, Div. Engineering

0014 GENETIC EFFECTS OF MICROWAVE RADIATION ON CHINESE HAMSTERS. Everts, J. M. (U.S. EPA, Natl. Environ. Res. Ctr., Durham, North Carolina 27711).

Sexually mature male and female Chinese hamsters are irradiated with microwave radiation (2450 MHz) at a power density of 200 mW/cm² for two minutes. The animals are then bred and the litters observed for variation from the norm of the colony. Blood leukocyte cultures are prepared from the offspring which reach weaning age and the cells are scored for chromosome anomalies. This study is designed to give an indication of the presence or absence of

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gross genetic effects elicited by microwave radiation.
(8/71-1/73).

SUPPORTING AGENCY:EPA, Off. Res. & Develop.

0015 EFFECTS OF ELECTROMAGNETIC FIELDS ON
GENETIC PHENOMENA. Braver, G. (U.
Oklahoma Sch. Arts, Norman, Oklahoma 75069).

The investigators propose to examine the biological effects of various configurations of electromagnetic fields at levels which are below the range where thermal effects are evident. They will study the biological indices provided by mutations, specifically sex-linked lethals, recombinations and non-disjunction of the X-chromosome in *Drosophila melanogaster*. (7/72-6/73)

SUPPORTING AGENCY:EPA, Off. Res. & Develop.

0016 BIOCHEMICAL MEASURES OF MICROWAVE INDUCED
STRESS. Schwarz, H. P. (Philadelphia Gen.
Hosp., Philadelphia, Pa. 19104).

Plasma samples from human subjects under various conditions of stress and from animals irradiated with nonionizing radiation under various frequencies will be analysed for phospholipid distribution to correlate changes with the intensities and duration of the stress. Two-dimensional thin layer paper chromatography of deacetylated phospholipids will be used to separate the individual phospholipids extracted from plasma. Quantitation will be achieved by colorimetric determination. (7/72-6/73)

SUPPORTING AGENCY:Department of Defense, Naval Air
Develop. Ctr., Crew Systems Dept.

0017 IONIZING AND NON-IONIZING RADIATION
BIOLOGY. Appleby, A. (Rutgers State U.,
Agricultural Exp. Sta., New Brunswick, New Jersey
08903).

The effect of chronic low level microwave exposures on the mammalian anterior lens as they relate to cataract formation at various age levels will be evaluated. Fundamental data relevant to the understanding of the chemical and biological processes involved in the interaction of radiations with organisms will be gathered; such data being directed towards the development of practical means to inhibit, neutralize or reverse the biological damage caused by radiation. The mitotic index of chosen mammalian species will be measured using a tritiated thymidine-autoradiography technique of different age groups after various exposure periods, followed by the observation of cataract producing doses. The relative radiation sensitivity of experimental animals (e.g. rats) with or without treatment by radiated gas will be determined by standard procedures. The objects

of the study are to calibrate a 2450 MHz microwave oven as a specimen irradiator and determine subsequently the effects of microwaves on thyroid function in the mouse. Calibration by colorimetry was carried out successfully. Preliminary results on the test animals showed no significant changes in thyroid function following single or multiple exposures at various power levels. (7/73-6/74).

SUPPORTING AGENCY:New Jersey State Government

0018 *BRACON*, AN ASSAY FOR GENETIC EFFECTS OF
MICROWAVES. Valcovic, L. R. (Auburn U.,
Agricultural Exp. Sta., Auburn, Alabama 26830).

An assay for possible genetic and physiological effects of 2450 MHz radiations using the parasitic wasp, *Bracon hebetor* will be carried out. Mature sperm and all stages of oogenesis will be surveyed for mutational effects, particularly dominant and recessive lethal mutations. Two experiments have been completed since the beginning of the grant period. In the first, female wasps were exposed to 2450 MHz microwaves for 30, 60, and 90 minutes. Analysis indicates that these exposures did not cause any significant changes in fecundity, fertility, or life span. Adult males were exposed to the same levels of radiation in the second experiment. The biological parameters studied were dominant and recessive lethals and sperm inactivation. This experiment also failed to detect any significant damage with these levels of irradiation. The power density in the exposure area for both experiments was 200 mW/cm². (7/72-6/73).

SUPPORTING AGENCY:Alabama State Government

0019 EFFECTS OF MICROWAVE RADIATION ON NAVAL
PERSONNEL. Beischer, D. E.; Reno, V. R.
(U.S. Navy, Aerospace Med. Res. Lab., Pensacola,
Florida 32512).

Exposure of naval personnel to microwave radiation is an acute problem. Even low doses are likely to reduce the efficiency of personnel in vital duty positions. The maximum safe exposure level presently endorsed by all branches of the armed forces (10 mW/cm²) is based on extrapolation from animal experiments and does not take into account duration of exposure or frequency of radiation. The great uncertainty in setting safe limits is best illustrated by the wide gap between the U.S. and Soviet limits, with the U.S. limit higher by a factor of 1000 than the Soviet level. Present and future use by the Navy of microwave radiation of increasingly higher power in a wide band of frequencies makes it mandatory to establish safe levels of exposure using the results of well controlled laboratory exposure of human subjects as a guide line. Human volunteers will be exposed to microwave radiation in the 1 to 12.4 GHz range, and the physiological and psychological effects observed. Exposure time and maximum power

density will be increased gradually, starting from the Soviet levels and approaching but not surpassing the intensity level considered at present to be safe in the U.S. Objective test methods will be used to detect possible neurological decrements (aesthetic syndrome), sleepiness in daytime, fatigue, reduced memory and inability to make decisions. (7/72-6/73)

SUPPORTING AGENCY: Department of Defense, Naval Aerospace Med. Res. Lab.

0020 SIMULATION OF OTH RADAR HF RADIATION FIELDS.
Hurt, W. D.; Hardy, K. A. (USAF, Sch.
Aerospace Med., San Antonio, Texas 78235).

The primary objective of this project is to develop and implement a system and technique for exposing biological samples to HF band radiofrequency (RF) electromagnetic radiation fields. This system will be used to better define personnel exposure criteria for priority operational RF radiation environmental situations. Current exposure guidelines, as presented in AFM 161-7, may not be appropriate for HF bands (3-30 MHz). Initial efforts will be directed to the installation and operational checkout of an AN/FRT-6B transmitter. The RF exposure enclosure currently being used in support of the engineering services project for ESD will be modified to accommodate the AN/FRT-6B transmitter. (7/72-6/73)

SUPPORTING AGENCY: Department of Defense, USAF Sch. Aerospace Med.

0021 THE EFFECTS OF MICROWAVE RADIATION ON THE
BRAIN MECHANISM REGULATING METABOLISM AND
BODY TEMPERATURE. Squires, R. D. (U.S. Navy, Crew
Systems Department, Warminster, Pennsylvania 18974).

The object of this project is to assess the effects of microwave radiation on the central nervous system in order to aid the establishment of maximum exposure standards for aircrews. A new metabolic chamber will be used to measure the metabolic responses of test animals in terms of oxygen consumption and brain colonic temperatures, while they are being subjected to microwave radiation confined to their heads. The radiation intensity levels will be in accordance with those experienced by aircrewmembers exposed to microwave (radar) radiation. (7/72-6/73)

SUPPORTING AGENCY: Department of Defense, Naval Bureau of Med. Surg.

0022 CRITICAL REVIEW: BIOLOGICAL EFFECTS OF
MICROWAVE IRRADIATION. Baranski, S.
(Coord. Comm. Pol. Amer. Collab., Warsaw, Poland).

The use of microwave generators in industry, radio-navigation, radio-communication, radio-location and research will be reviewed and the possible hazards

for personnel employed within the compass of irradiation will be identified. The physical characteristics of microwave exposure and methods, for application to the prevention of health hazards stemming from continued exposures to microwave irradiation, will also be identified. A monograph (approx. 350 p) will be published for international use in research to reduce the effects of microwave irradiation and improve methods of treatment. The monograph will include supporting tabulations and photographs. (7/72-6/73)

SUPPORTING AGENCY: HEW, Publ. Hlth. Service, Natl. Inst. Hlth., Fogarty Internatl. Ctr.

0023 NAVY ENVIRONMENT: PHYSIOLOGICAL, PATHO-
LOGICAL AND BEHAVIORAL EFFECTS OF MICROWAVE
RADIATION. Hunt, E. L.; Phillips, R. D. (Battelle
Mem. Inst., Pacific NW Labs., Richland, Washington
99352).

This investigation is part of a Navy program to evaluate the potential hazards of microwave radiation to Navy personnel. Young pathogen-free rats will be exposed to microwave irradiations under two sets of conditions. Rats will be exposed in the Fraunhofer range of a horn in an anechoic chamber which provides a unilateral exposure to a well-defined field, but which has the drawback that absorbed energy cannot be measured. As a complementary procedure, rats will be exposed in a multilateral resonating cavity in which the field is shifting and complex. However, energy absorbed by the animal can be (indirectly) measured. Radiation effects will be assessed through observation of excitability of the central nervous system as manifested by the decrease in threshold response to electrically induced convulsions. Other response parameters may be included. A Navy S-band (and later an X-band) radar source will be used to provide an average field intensity of 50 mW/cm² in both types of exposure. (7/72-6/73)

SUPPORTING AGENCY: Department of Defense, Off. Naval Res.

0024 NAVY ENVIRONMENT: X-RAY AND MICROWAVE
RADIATION INTERACTION WITH MUSCLE CELLS.
APPLICATION TO PROTECTION AND TREATMENT. Portela,
A.; Perez, J. C. (Consejo NAC, De Inv. Clien. Tec.
Buenos Aires, Argentina).

This research seeks to identify and characterize in cellular and subcellular structures the critical membrane systems, organelles and biochemical mechanisms which are affected by the absorption of ionizing (X-rays) and nonionizing (microwaves) radiation likely to exist in the environment of naval personnel. Efforts will be made to develop specific agents to prevent or counteract undesirable effects of these radiations. The area and nature of radiation damage at the cellular and subcellular level is being investigated *in vivo* and *in vitro*, using skeletal muscles of frogs and

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rats, with special micro techniques developed by the principal investigator. Changes in ion transport, conductance, and incorporation of physiologically important chemicals are analyzed. The insight gained into the mechanisms of damage to the membranes and cells then serves as a guide to the design, selection, and testing of possible therapeutic and prophylactic agents. (7/72-6/73).

SUPPORTING AGENCY: Department of Defense, Off. Naval Res.

0025 NAVY ENVIRONMENT: BIOLOGICAL EFFECTS OF MICROWAVES AND ELECTRIC FIELDS. Schwan, H. P.; Kirtikos, H. (U. Pennsylvania, Sch. Electrical Engineer., Philadelphia, Pa. 19104).

The possible hazards of present microwave exposure limits will be investigated with respect to the safety of naval radar operations. Experiments are designed to investigate two hypotheses: (1) that microwave-induced hot spots in the brain and other parts of the body emit frequencies resonant with microwaves or (2) that the conductivity of human tissues is high enough to dampen such resonances. Pertinent field equations will be applied to models with dielectric properties similar to the human brain. Extensive calculations will be made by computer. (7/72-6/73)

SUPPORTING AGENCY: Department of Defense, Off. Naval Research

0026 CYTOGENETIC EFFECTS OF MICROWAVE RADIATION ON TISSUE CULTURE. Everts, J. M. (U.S. EPA, Natl. Environ. Res. Ctr., Durham, North Carolina 27711).

Cultured cells will be irradiated with 2450 MHz microwave radiation for varying time intervals and varying power densities. Power density will range from 200 mW/cm² to 15 mW/cm². Chromosome analysis will follow the irradiation procedure at appropriate time intervals. This data will provide information regarding variations in percentage of chromosome aberration associated with time and power density variations. (9/1/72-1/1/74).

SUPPORTING AGENCY: EPA, Off. Res. & Develop.

0027 NAVY ENVIRONMENT: EVALUATION OF THE SAFETY EXPOSURE LIMITS OF RADAR USED BY NAVAL PERSONNEL. Hunt, E. L.; Phillips, R. D. (Battelle Mem. Inst., Pacific NW Labs., Richland, Washington 99352).

Naval personnel exposed to the powerful electromagnetic radiation of radar on shipboard may possibly suffer deleterious nervous effects, which are not immediately apparent, as a result of long-term

exposure. This research is designed to test for possible ill effects of chronic low-level microwave exposure. Physiological and behavioral effects of single, repeated and long-duration exposures to microwaves of various wavelengths are being studied in rats. Studies of the central nervous system reactivity will ascertain whether decrements occur in sensory function, physical performance, temperature regulation, metabolic capacity and response to environment after exposure to microwaves. Specifically, rats will be monitored for temperature and observed for velocity and endurance in a 20 foot swim test. Ability to maintain normal temperature under cold stress (-17 C) and alertness in a vigilance task will also serve as criteria of physiological detriment from microwave exposure. (7/72-6/73)

SUPPORTING AGENCY: Department of Defense, Off. Naval Res.

0028 SCIENTIFIC AND TECHNICAL PROGRAMS FOR MONITORING OF ENVIRONMENTAL RADIATION LEVELS AND INVESTIGATION OF BIOLOGICAL EFFECTS. Grove, H. M. (U.S. Army, Walter Reed Army Inst. Res., Washington, D.C. 20012).

The agreement provides for cooperative scientific and technical programs for monitoring environmental radiation levels - radiofrequency and microwave energy, developing any special instruments required, and investigating biological effects of nonionizing electromagnetic radiation. (7/72-6/73).

SUPPORTING AGENCY: EPA, Off. Res. & Develop.

0029 NAVY ENVIRONMENT: QUANTITATION OF MICROWAVE RADIATION EFFECTS ON THE HEAD AND EYES OF RABBITS, PRIMATES AND MAN. Guy, A. W.; Pirotska, K. (Washington U., Sch. Med., St. Louis, Mo. 63110).

The conditions and mechanisms of cataract production by microwave irradiation will be ascertained and the results will be quantitatively extrapolated to human exposure problems. This research will involve a theoretical determination of the relation between the internal absorption characteristics of the animal and human eye and the microwave frequency and aperture size. An investigation will also be made into thresholds of eye damage caused by continuous and pulsed microwaves during acute and chronic exposure to frequencies between 200 MHz and 10 GHz. Recording temperature change in the tissue by means of thermographic and thermocouple techniques will improve dosimetry. Rabbits and monkeys will be used. Induced temperature rise and post-exposure cooling will be carefully monitored with hollow glass micropipettes placed in the eye so that thermocouples can be readily placed for temperature measurement. Electromagnetic field patterns, both in and near the tissue structures, will be quantitatively established as a function of frequency and source location. Acute exposures will be performed at radiation levels rang-

ing from 10 to 500 mW/cm². Pre-irradiation examinations will be made by slit-lamp biomicroscopy. Histological examinations will be performed on animals with significant ocular changes. (7/72-6/73)

SUPPORTING AGENCY: Department of Defense, Off. Naval Res.

0030 A PRELIMINARY SURVEY OF VETERANS WHO MAY HAVE BEEN EXPOSED TO CATARACT PRODUCING RADIATION. McAfee, R. D.; Cazenavette, L. L.; Holland, M. G. (U.S. VA Hosp., New Orleans, Louisiana 70140).

A shadow graph device which allows an individual to see opacities within the lens of his eye (or in the cornea) has been developed at this laboratory. It is an improved version of an old device known as a cataract viewer. This device is being mailed to a select population of veterans (with their approval) who may have been at risk from exposure to x- and microwave radiation. They are requested to draw what they see. If they see opacities in what should be clear field, follow-up examinations of these individuals will be made. Thus the shadow graph device is an inexpensive means for screening a population who may have been exposed to ionizing and microwave radiation, specifically individuals who have not worked with or on electronic equipment, will be included in the study. (7/72-6/73).

SUPPORTING AGENCY: Veterans Administration

0031 BEHAVIORAL AND EEG EFFECTS OF MICROWAVES. Cunitz, R. J.; Cornog, J. R. (U.S. Dept. Commerce, Natl. Bur. Stds., Washington D. C. 20234).

Two monkeys were exposed to radiation levels varying from 0.1 to 10,000 milliwatts absorbed power in a 400 MHz resonant cavity. They performed a four-choice serial reaction task, changes in their EEG rhythms were monitored and they were observed during exposure to the microwave source. Contrary to expectations, no change occurred in the level of arousal. The dosimetry technique employed permits a relatively accurate measurement of absorbed power and is less dependent on wavelength and body size than the usual field strength determination. Results from this study will be used to evaluate the effects of low level exposure and to establish human exposure standards. The experimental phase of the project has been completed (June 1973) and data analysis and report presentation are underway.

SUPPORTING AGENCY: EPA, Off. Res. & Develop.

0032 NAVY ENVIRONMENT: NEUROPHYSIOLOGICAL AND BEHAVIORAL EFFECTS DUE TO MICROWAVE IRRADIATION. Guy, A. W.; Lin, J. C. (Washington U., Sch. Med., St. Louis, Mo. 63110).

To provide a better understanding of microwave irradiation hazards and a scientific basis for safety standards, it is proposed that biological effects of continuous and pulsed microwaves be studied quantitatively. In addition, frequency and intensity factors will be investigated by controlled exposure of animals. The following research will be undertaken: (1) theoretical investigation of energy distribution in humans and animals after microwave radiation exposure; (2) thermographic determinations of temperature distribution in animals and phantom models; (3) observation of behavioral changes using operant conditioning techniques; (4) establishment of microwave influence on neurophysiological characteristics by using gross and single cell recordings of CNS-evoked responses. In the first phase of the work, a study will be made of the effects produced on recording electrodes which differ in composition and size. Results will be compared using fluid-filled electrodes of different ionic concentrations (4M vs Ringer's solution) to pinpoint any effects caused by ions driven out of the recording electrode to the vicinity of the cell. Fluid-filled electrodes will also be used to study the effects of microwaves on thalamic responses to sound stimulation. Heat distribution in the brain will be correlated with changes in response; thermographic studies will be performed on small animals and phantom spheres. The behavioral effects of direct microwave stimulation will be studied on cats, monkeys, mice and rats. (7/72-6/73).

SUPPORTING AGENCY: Dept. of Defense, Off. Naval Res.

0033 CYTOGENETIC EFFECTS OF MICROWAVE RADIATION ON CHINESE HAMSTERS (VARIABLE POWER DESTINY). Everts, J. M. (U.S. EPA, Natl. Environ. Res. Ctr., Durham, North Carolina 27711).

Chinese hamsters will be irradiated with 2450 MHz microwave radiation at accurately specifiable free field power densities for a predetermined time interval. The incident power density will vary from 200 mW/cm² to 15 mW/cm². Animals will be sacrificed and appropriate tissues cultured for chromosome analysis. This data will provide information regarding variations in percentage of chromosome aberrations associated with power density. (6/1/72-6/30/73).

SUPPORTING AGENCY: EPA, Off. Res. & Develop.

0034 ATHEROSCLEROSIS AND RADIO FREQUENCY IRRADIATION. Sparks, H. V. (U. Michigan Sch. Med., Ann Arbor, Michigan 48104).

The effect of radio frequency irradiation on the development of atherosclerosis in rabbits, rats, and squirrel monkeys will be studied. All animals will be fed an atherogenic diet and one group of animals will be irradiated while others serve as controls. After several months the animals will be sacrificed and their aortas will be analyzed for the extent of intimal involvement in the athero-

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sclerotic process (gross), the extent of invasion of the media by foam cells (microscopic) and the cholesterol content of the aorta wall. The effect of frequencies between 10^5 and 10^9 Hz will be tested as will the effect of a range of field strengths between 0.5 and 50 V/meter. To test the hypothesis that radio frequency irradiation causes arterial wall injury we will study the microscopic anatomy of the irradiated aortic wall in the absence of hypercholesterolemia. We will also study the effects of radio frequency irradiation on blood pressure and serum cholesterol concentration. (9/73-8/74).

SUPPORTING AGENCY:HEW, Publ. Hlth. Serv., Natl. Heart & Lung Inst.

0035 RADIOFREQUENCY CORDOTOMY OF THE LUMBOSACRAL CORD FOR RELIEF OF SPASTICITY IN MAN. Katz, M. R. (Temple U. Grad. Sch., Philadelphia, Pa. 19122).

The object of this project is to test the hypothesis that radiofrequency (RF) cordotomy is an effective method of treatment for spasticity of spinal cord origin in man. RF cordotomy of the lumbosacral cord will be induced in each of 3 patients with complete physiological and clinical transection of the spinal cord. Subjects will present severe clinical spasticity of the flexors of the hip, adductor of the hip, and flexor of the knee. (7/72-6/73).

SUPPORTING AGENCY:HEW, Soc. & Rehabil. Serv., Off. Res. Demons. & Trng., Res. & Trng. Ctr. Div.

0036 QUANTITATIVE EFFECTS OF ELECTROMAGNETIC ENERGY ON HUMAN TISSUES. Guy, A. W. (U. Washington Sch. Med., Seattle, Washington 98105).

This study is designed to illuminate areas in which more quantitative information is required to establish realistic safety standards in regard to effects of electromagnetic fields on biological tissues and systems. Animals and human volunteers are exposed to selected sources of electromagnetic energy and electromagnetic field patterns are established quantitatively as a function of frequency, source configuration and source location. Effects on the central nervous systems and other factors such as genetic and behavioral patterns are quantified by engineering and medical technology. The results are as follows: (1) Exposure of cat's head to 918 MHz microwave irradiation increased brain temperature and thus altered central nervous system responses. Recordings from the thalamic area indicate that changes occur only if the exposure level is thermally significant. (2) Fluid filled glass electrodes of ionic concentration other than Ringer's solution (e.g. 4M), when irradiated with electromagnetic energy, produced artifacts as data. Insulated metal electrodes also yielded unorthodox responses. (3) Filters have been developed to eliminate artifacts in recordings from the brain. (4) Electromagnetic field and heating patterns and absorption of energy have been determined for exposure of the brain and the total body in both

humans and animals. (5) Dosimetry instrumentation has been developed to measure fields actually induced in tissues. (7/72-6/73)

SUPPORTING AGENCY:HEW, Soc. & Rehabil. Serv., Off. Res. Demon. & Trng., Res. & Trng. Ctr. Div.

0037 NAVY ENVIRONMENT: EFFECTS ON BIOLOGICAL SYSTEMS DUE TO MICROWAVE IRRADIATION. Durney, C. H.; Lords, J. L. (Univ. Utah, Sch. Engineering, Salt Lake City 84112).

This research investigates the possible damage caused by exposure to low-power microwave radiation. The response of isolated turtle hearts and *in situ* dog hearts will be studied. In addition, development of a nonperturbing temperature probe based on fiber optics illuminating system and a liquid crystal detecting system will be undertaken. Hearts from freshly killed turtles are placed in Ringer's solution and a record of physical and electrical activity taken until stabilization occurs. Microwave power is then delivered to the heart and the activities of the heart recorded. Microscopic studies will then reveal microstructural defects. A waveguide catheter system small enough to be passed into the venous or arterial circulatory system of the dog will be designed. This allows *in situ* irradiation of the interior of the dog heart both acutely and chronically. Temperature sensitive liquid crystals are to be used in conjunction with a fiber optic illuminator-display to possibly develop a nonperturbing probe for temperature measurement in biological media in the presence of a microwave field. (7/73-6/74)

SUPPORTING AGENCY:Off. Naval Res., Dept. of Defense

0038 EFFECT OF MICROWAVE RADIATION ON NERVOUS ACTIVITIES. Kritikos, H. N.; Takashima, S. (Univ. Pennsylvania, Sch. Engineer., Philadelphia 19104).

This research examines the effects of low dose microwave radiation on nervous activities of invertebrates. These effects can be extrapolated to mammals with a considerable degree of assurance. The non-thermal effects of low dose radiation on the central nervous system of mammals has been debated by investigators for many years with considerable divergence of opinion. Nervous activities are based on intricate neuron networks that can be disturbed by even low dose microwave radiation. Experiments have resulted in evidence of symptomatic disorders in human subjects. With low dose irradiation, changes in behavioral patterns such as irritability, headache and memory difficulties have been observed. This research will aid in understanding the complex relationships that exist in this area. (8/73-7/74)

SUPPORTING AGENCY:NSF, Div. Engineer.

0039 MIXED RF/IONIZING RADIATION EFFECTS. Krupp, J. H. (U.S. Air Force, Sch. Aerospace Med., San Antonio, Texas 78235).

The effect of combination ionizing and nonionizing radio frequency (RF) fields will be investigated in experimental animals. The animals will be housed in a climate controlled, low dose rate facility which will allow exposure to any desired continuous dose rate between 100 millirad and 20 rad per day, either alone or simultaneously with radio frequencies ranging from 40-400 MHz and 1-3.5 GHz. This facility can be used to test such parameters as performance capabilities on trained tasks, hematological and biochemical variations and organ function tests. Because air crew and other personnel will be exposed to combination ionizing and nonionizing RF fields in operations involving high altitude, nuclear propulsion and isotope power sources, subclinical injury and long term delayed effects of RF fields must be evaluated. The findings of this study will be correlated with available human data, including the Oak Ridge Facility, in an attempt to make realistic extrapolations to humans. (7/73-6/74)

SUPPORTING AGENCY:USAF Sch. Aerospace Med., Dept. of Defense

0040 COMBINED STRESS STUDIES IN HF BAND FIELDS.
Cupello, J. M. (USAF, Sch. Aerospace Med., Brooks AFB, San Antonio, Texas 78235).

The objective of this effort is to evaluate biological responses under combined temperature and radio frequency (RF) radiation stress. Plexiglas environmental chambers will be designed and constructed for experimental animals undergoing RF radiation exposure. These chambers will permit control of temperature and relative humidity. The effects of heat stress on the animal during RF radiation exposure, which overburdens the heat dissipation mechanism, will give an indication of effect of combined stress in RF fields. Monitoring of the chamber's input and output temperature and relative humidity will allow quantitation of the amount of heat generated which is due to RF radiation. Larger chambers will be constructed at a later date to perform this same study on *rhesus* monkeys. Results will be applied to exposure standards for Air Force personnel. (7/73-6/74)

SUPPORTING AGENCY:USAF Sch. Aerospace Med., Brooks AFB

0041 BIOLOGICAL EFFECTS OF PULSED ELECTROMAGNETIC FIELDS. Skidmore, W.; Brunhart, G. (Armed Forces Radiobiol. Res. Inst., Bethesda, Maryland 20014).

The objective of this research is to determine biological hazards associated with long term exposure to electromagnetic pulsed fields (EMP). Sixty male leukemia-prone mice (AKR-J), 20 mammary tumor-prone female Sprague-Dawley rats and 150 male rats to be serially sacrificed for bioassay data will be exposed continuously (23 hr/day) in an EMP field for approx 1 yr. An equal number of animals will serve as controls. The exposure

will consist of 1 pulse/second with a peak field intensity up to 500 KV/M and a mixed frequency component up to 100 MHz. Data will be evaluated to determine if any abnormal biological effects such as an increased incidence and rate of neoplasms, changes in hematological parameters, increased chromosomal aberrations, etc., occurred during the exposure period. Results will be applied to potential occupational hazards associated with long term exposures to electromagnetic pulsed fields. (7/73-6/74).

SUPPORTING AGENCY:Armed Forces Radiobiol. Res. Inst.

0042 CYTOGENETIC EFFECTS OF MICROWAVE RADIATION ON CHINESE HAMSTERS (VARIABLE POWER DENSITY). Everts, J. M. (Nat'l. Environ. Res. Center, Durham, N.C. 27711).

The contract for this project was renewed for 7/73-6/74. Please refer to abstract #0033, page 35 in Volume 1, Issue 1 of the *Biological Effects of Electromagnetic Radiation Digest* for a project description.

SUPPORTING AGENCY:EPA, Off. Res. and Dev.

0043 EMP EFFECTS ON CARDIAC PACEMAKER. Brunhart, G. (Armed Forces Radiobiol. Res. Inst., Bethesda, Maryland 20014).

This study will seek to determine (1) the physiological effects of EMP interference on electronic cardiac pacemaker wearers and (2) the physical effects on the pacemaker circuits and components. A literature search will be conducted. Both a hypothesized model and mathematical analysis will be used to predict effects. Bench testing and *in vivo* testing will be carried out to verify the model. At each stage of testing, the model will be modified as necessary. (7/73-6/74)

SUPPORTING AGENCY:Armed Forces Radiobiol. Res. Inst.

0044 PROGRAM ON THE QUANTITATION OF THE EFFECTS OF ELECTROMAGNETIC ENERGY ON HUMAN TISSUE. Guy, A. W. (Univ. Washington, Med. Rehabil. Res. Tr. Ctr., Seattle 98105).

Test animals are exposed to selected sources of electromagnetic energy to quantify observable effects and biological changes. The electromagnetic field patterns, both in and near the tissue structures, are quantitatively established as a function of frequency, source of configuration and source location. Progress in the project is as follows: (1) Power absorption patterns have been measured in cat brains, rat bodies, and rabbit heads and eyes. Physiological changes were noted in the tactile and auditory systems of cats. Equivalent changes were noted when a cat's head was heated using a non-microwave heating-heat exchanger. Radiation changes can be counteracted by cooling the affected tissues. (2) Cataracts were produced by microwaves near the posterior pole of the rabbit eye lens at microwave power levels producing temperatures at 42 C. (3) Non-

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thermal levels of pulsed microwaves were noted to produce auditory sensations in humans at pulse energy densities of 20-40 Microfarads/cm². Experiments on cats show that the microwave pulses stimulate the auditory system via the inner ear. (4) The electrical characteristics of isolated peripheral nerves of frogs and cats under controlled temperature conditions did not change under radiation power levels as high as 4 watts/cm² as long as the temperature was kept constant. Data from this research indicate that microwaves may be used to transmit energy safely through tissue from the outside to power implanted microsize nerve stimulators. Implanted packages as small as a cubic millimeter appear to be feasible for nerve stimulation to block pain or activate denervated muscles. The project hopes to provide realistic guidelines for safety standards related to human exposure to electromagnetic radiation. (7/73-6/74)

SUPPORTING AGENCY:HEW, Soc. Rehabil. Serv., Off. Res. Demons. Trng., Res. Trng. Ctr. Div.

0045 CYTOGENETIC EFFECTS OF MICROWAVE RADIATION ON TISSUE CULTURE. Everts, J. M. (Nat'l. Environ. Res. Ctr., Durham, N. C. 27711).

The contract for this project was renewed for 7/73-6/74. Please refer to abstract #0026, page 34, in Volume 1, Issue 1 of *Biological Effects of Electromagnetic Radiation Digest* for a project description.

SUPPORTING AGENCY:EPA, Off. Res. and Dev.

0046 NAVY ENVIRONMENT: MUTAGENIC EFFECTS DUE TO MICROWAVE RADIATION GENERATED BY NAVAL OPERATION. Varma, M. M.; Joshi, S. R. (Howard Univ., Sch. Engineering, Washington D. C. 2001).

This research will evaluate the mutagenicity of microwaves as a function of frequency, exposure time and power level. The testes of male mice will be irradiated. To avoid struggling during restraint, the mice will be anesthetized with phenobarbital. After each exposure the males will be mated with three unexposed virgin females for five days. The females will be replaced weekly for a total of eight consecutive weeks. Mated females, as evidenced by the presence of a vaginal plug will be dissected on the thirteenth day of the pregnancy and the total number of implants, viable implants, and early and late foetal deaths will be recorded. The results will be compared with concurrent control groups. Adverse genetic effects will be studied by observation of the F₁, F₂ and F₃ progeny of exposed male mice. (7/73-6/74)

SUPPORTING AGENCY:Off. Naval Res., Dept. of Defense

0047 RADIO FREQUENCY HEAT FOR CANCER THERAPY. Edwards, W. S.; Doss, J. D.; Weiss, G. K.; Key, C. (Univ. New Mexico, Sch. MEd., Albuquerque 87106).

Recent reports from several investigators suggest

that malignant cells are as much as twice as susceptible to heat as corresponding normal cells. Clinical trials in the last twenty years have demonstrated that superficial tumors do respond to heat, but its usefulness could not be thoroughly explored because there was no way to localize heat to volumes of tissue beneath the skin or mucous membranes. Radiofrequency current offers such an opportunity. Preliminary experiments have shown that a standard sarcoma transplanted to mice can be made to disappear without damage to the overlying skin using heat generated by radiofrequency current and these tumors have not recurred in a six month period of follow-up. We plan to explore this further to determine very carefully the dose response curve of this tumor by varying the temperature and time of exposure. We will then determine the dose response curve of normal skin, mucous membrane and many other organs and tissues. We have developed an animal tumor referral system that will allow us to test the effectiveness of radiofrequency current on many spontaneous malignancies in dogs, cats and mice and to facilitate the development of radiofrequency electrodes for internal as well as external therapy. The combination of surgical removal of the bulk of tumors, then treatment of the residual with radiofrequency heat will also be tested. (1/74-12/74)

SUPPORTING AGENCY:HEW, Publ. Hlth. Serv., Nat'l. Cancer Inst.

0048 EFFECTS OF MICROWAVE RADIATION ON GROWTH AND DEVELOPMENT OF EMBRYO CELL SYSTEMS. Barnes, F. S.; Gamow, E. (Univ. Colorado, Sch. Engineer., Boulder 80302).

Irradiated chick embryos will be observed and assayed in order to detect growth cycle related deviations which may exhibit some degree of latency. A microwave system will be designed and constructed for the irradiation of the embryos such that the energy field incident on the test specimen is known and reproducible. Exposures will be made at varying times of development, with emphasis on critical periods of organ system differentiation. Microscopic examination will be made as indicated on embryos dying prematurely, and routinely on selected embryo systems. Of particular interest would be areas of tissue containing those highly specialized cells which are determinants for vital organ structures, e.g. neural crest cells and cardiovascular precursors. Cell cycle studies will be used to evaluate the existence of microwave resistant or sensitive phases in cellular metabolism. Standard biophysical techniques will be employed in cell culture production and evaluation. Exposures at various phases of cell growth will be utilized to assay the possible nonthermal effects of RF radiation on cell growth kinetics. Data will be used to establish safety criteria and operational procedures for Air Force personnel. (7/73-6/74)

SUPPORTING AGENCY:USAF Sch. Aerospace Med., Brooks AFB

0049 SCIENTIFIC AND TECHNICAL PROGRAMS FOR

**MONITORING OF ENVIRONMENTAL RADIATION LEVELS
AND INVESTIGATION OF BIOLOGICAL EFFECTS.** Sharp, J. C.
(U.S. Army Reed Inst. Res., Washington D. C.).

The contract for this project, formerly headed by H. M. Grove, was renewed for 7/73-6/74. Please refer to abstract #0028, page 34 in Volume 1, Issue 1 of the *Biological Effects of Electromagnetic Radiation Digest* for a project description.

SUPPORTING AGENCY: EPA, Off. Res. and Dev.

**0050 INVESTIGATION OF RADIO FREQUENCY AND
MICROWAVE RADIATION INDUSTRY.** Conover,
D. (HEW Publ. Hlth Serv., Cincinnati, Ohio 45202).

Current OSHA Regulations include occupational exposure limits for RF/Microwave radiation over the frequency range from 10 MHz to 100 GHz. Instrumentation is not available for detecting hazardous exposure levels for non-ionizing radiation with frequencies below 300 MHz. Little is known about the biological effects of RF/Microwave radiation on humans at assigned industrial, scientific and medical (ISM) frequencies of 13, 27, and 40 MHz; however, industrial uses of these frequencies are rapidly increasing. Consequently a survey of application of 13, 27 and 40 MHz radiation in industry is planned to determine the potential limits for occupational exposure and to identify health and safety problems experienced as a result of these uses. Efforts will also be made to develop a monitoring instrument for use over the 10 MHz to 300 MHz frequency range. (7/73 - 6/74)

SUPPORTING AGENCY: HEW, Publ. Hlth Serv., Natl. Inst. Occupational Saf. Hlth.

**0051 GENETIC EFFECTS OF MICROWAVE RADIATION
ON CHINESE HAMSTERS.** Everts, J. M.
(Natl. Environ. Ctr., Durham, N. C. 27711).

The contract for this project was renewed for 7/73-6/74. Please refer to abstract #0014, page 31, in Volume 1, Issue 1 of *The Biological Effects of Electromagnetic Radiation Digest* for a project description.

SUPPORTING AGENCY: EPA, Off. Res. and Dev.

**0052 DEVELOP AND VALIDATE EQUATIONS TO ALLOW
EXTRAPOLATION OF RF ANIMAL DATA TO MAN
FOR HAZARD ASSESSMENT PURPOSES.** Guy, A. W. (Univ.
Washington, Sch. Med., Seattle 98105).

The purpose of this effort is to develop mathematical models of the interaction of electromagnetic fields with man. These equations are necessary because of the increased recent concern about electromagnetic pollution of the environment and possible deleterious effects on humans. Accurate prediction of power deposition and distribution coupled with thermal flux equations are necessary elements for formulating AF safety criteria. Known tissue conductivities, dielectrics and loss tangents will be used to model electromagnetic in-

teractions with a two-meter 70 kg normal man. Thermal flux equations will be utilized to determine rates of heat flux away from sites of dielectric discontinuity and predict temperature changes of those sites. The gross core temperature change can be determined, in principle, by integrating heat flux from such sites and comparing it with normal heat loss mechanisms. Considerable difficulties are introduced by the lack of formal conformation of man or other animals. Such departures from regular ellipsoidal objects introduces great difficulty in finding general solutions for appropriate field equations, and will probably necessitate a semi-empirical approach to some partial solutions. For this reason, elementary circuit analysis, heat flux and circulatory dynamics within published state-of-the-art are the purpose of this effort. A later effort, based on equations developed here, will be undertaken to refine frequency domain interactions and field vector interactions. (7/73-6/74)

SUPPORTING AGENCY: USAF Sch. Aerospace Med., Brooks AFB

**0053 NAVY ENVIRONMENT: X-RAY MICROWAVE RADIATION
INTERACTION WITH MUSCLE CELLS. APPLICATION
TO PROTECTION AND TREATMENT.** Portela, A.;
Perex, J. C. (Consejo Nac. De Inv. Cien. Tec.,
Buenos Aires, Argentina).

The contract for this project was renewed for 7/73-6/74. Please refer to abstract #0024, page 33 in Volume 1, Issue 1 of the *Biological Effects of Electromagnetic Radiation Digest* for a project description.

SUPPORTING AGENCY: Off. Naval Res., Arlington, Virginia

**0054 BIOLOGICALLY IMPORTANT RF POWER ABSORPTION
MEASUREMENTS FOR SAFETY CRITERIA.** Howell,
W. A. (Block Engineering Inc., Cambridge, Massachusetts 02139).

Molecular level perturbations caused by radiofrequency (RF) fields will be measured. Genetic or long term effects of RF radiation, if any exist, must ultimately affect at least one of the large molecular species important in cell function. Consequently, the effects of RF fields on large molecular species in a water solution will be studied. Only a water solution, whose constituent subunit (nucleotides or amino acids) is well-documented and which can be obtained in highly pure form will be used. These substances including pure RNA-ase, pure virus RNA, nucleotides, amino acids, and poly amino acids are to be dissolved in aqueous buffers and subjected to RAMAN determination of group vibrational amplitudes during application of RF fields and programmed temperature changes. Any effects of RF fields should be revealed in resonant line broadening and in alteration of polarization dependence or resonant absorption. Frequencies will range from 3 to 100 MHz with electric field equivalent to 3 KV/meter. Data will be used to formulate hazard criteria and safety

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standards. (7/73-6/74)

SUPPORTING AGENCY:USAF Sch. Aerospace Med., Brooks AFB, Texas

0055 STUDY OF BRAIN METABOLISM THROUGH MICROWAVE HEATING. Stavinoha, W. B.; Medina, M. A. (Univ. Texas, Sch. Med., San Antonio, Texas 78229).

Microwave radiation will be used to accomplish brain enzyme inactivation times of 1.5 seconds in the rat and 0.3 seconds in the mouse. Using this technique, studies of intermediary metabolism, cyclic nucleotide and the cholinergic system in whole brain and brain areas will be carried out. The effect of morphine will then be studied in this system. Further works will be done to decrease the microwave exposure time and to adapt the system to sacrifice unrestrained rats.

SUPPORTING AGENCY:HEW, Publ. Hlth. Serv., Natl. Inst. Mental Hlth.

0056 STUDY OF GENETIC EFFECTS OF MICROWAVE RADIATIONS. Hungate, F. P.; Felix, W. D.; Hunt, E. L. (Battelle Mem. Inst., Richland, Washington 99352).

A sensitive method of evaluating the dose absorbed during exposures to 2450 microwaves has been established by measuring light emission from a suspension of luminescent bacteria stabilized in a non-dividing form. Mutation frequencies are measured in these bacteria subsequent to exposure by the method of auxotroph reversion. This exposure system will be used to study forward mutation among the genes controlling light emission by identifying the frequency of colonies on plates which emit light at 23 C but not at 37 C. Since cell division and mutation are related, an exposure procedure will be developed in which light emission can be followed in growing cells during microwave exposures. This will enable one to evaluate mutation in dividing cells and also to chronically expose cells to lower dose rates over longer time periods. To make the data more representative of diverse species, other microorganisms whose genetics have been more extensively studied will be exposed under conditions identical to those used with the luminescent organisms and the mutation frequencies will be evaluated. A continuous wave source is sought for attachment to the exposure chamber. If one is obtained, mutation frequencies produced by continuous as well as pulsed sources will be compared. The same techniques of measuring absorbed dose will be utilized for both. (2/74-1/75)

SUPPORTING AGENCY:HEW, Publ. Hlth. Serv., FDA, Bur. Foods

0057 BIOLOGICAL EFFECTS OF VLF BAND ELECTROMAGNETIC RADIATIONS. Birgel, S. H. (SW Res. Inst., 8500 Culebra Rd., San Antonio, Texas 78228).

The objective of this project is to determine the observable effects of very low frequency (VLF) radiation on growth, reproduction, tumorigenesis, lymphocyte division, gross biochemistry or pathology of mice. Since existing safe level determinations (10 MW/cm²), used for the entire nonionizing portion of electromagnetic (EM) spectrum, are based on very high microwave frequency studies they do not reflect the extremely low biological power absorption associated with low and VLF radiation. A well-documented (C³H) strain of mice will be obtained as pregnant dams. The litters will be divided and the total number controlled such that litter mates will serve as nonradiated controls. Throughout life a daily radiation schedule (minimum 1 hr/day) will be followed. Radiation fields are to be produced in a coil-capacitor arrangement allowing development of 15 KV/meter fields. A variety of models in addition to the liver animals will be observed with thermography and temperature detectors. Animals will donate lymphocytes for culturing; examination will be made for chromosomal abnormalities, growth curve changes, food and water consumption, and urinary output throughout the experiment. Radiated animals are to be bred and the offspring examined for any abnormalities, including growth. All animals are to be screened for pathological changes during the course of the experiment. Data will be used to formulate operational safety criteria. (7/73-6/74)

SUPPORTING AGENCY:USAF Sch. Aerospace Med., Brooks AFB, Texas

0058 NAVY ENVIRONMENT: NON-THERMAL HAZARDS OF EXPOSURE TO RADIO FREQUENCY AND MICROWAVE FIELDS. Mickey, G. H. (New England Inst. Inc., Ridgefield, Conn. 06877).

The contract for this project was renewed for 7/73-7/74. Please refer to abstract #0012, page 31 in Volume 1, Issue 1 of the *Biological Effects of Electromagnetic Radiation Digest* for a project description.

SUPPORTING AGENCY:Off. Naval Res.

0059 THE EFFECTS OF EXTREMELY LOW FREQUENCY (ELF) RADIATION ON MAN. Beischer, D. E.; Grissett, J. D. (U.S. Navy, Aerospace Med. Res. Lab., Pensacola, Florida 32512).

Possible biological effects of extremely low frequency radiation (ELF) will be investigated. Controlled systematic laboratory exposure tests will progress in stages using a frequency below 100 Hz: (1) short-term exposure of lower primates and then human volunteers and (2) several months of ELF radiation exposure. In each case physiological and psychological tests will be used to measure metabolic effects, autonomic nervous system responses and central nervous system performance. The results of the project will provide an urgently needed database which the Navy can employ in establishing safe operational standards. (7/73-6/74)

SUPPORTING AGENCY:Dept. Defense, Navy

0060 EFFECTS OF MICROWAVES ON CNS, LIVER AND
HEART. Albert, E. N. (George Washington
Univ. Sch. Med., Washington D.C. 20037).

The purpose of this project is to investigate the ultrastructural effects of 2450 MHz microwaves on the central nervous system, heart and liver of Chinese hamsters. The animals will receive whole body irradiation at various power densities. They will then be sacrificed and prepared for morphological observations. Total synthesis and utilization of ATP and protein per gram of tissue will be measured in control and experimental animals. (10/73-9/74)

SUPPORTING AGENCY:HEW, Publ. Hlth. Serv.

0061 MICROWAVE DOSE-RESPONSE RELATIONS ON
TWO BEHAVIORAL TASKS. Galloway, W. D.
(Bur. Radiol. Hlth., Rockville, Maryland 20852).

The objective of this project was to determine if microwave irradiation at 2450 MHz continuous wave of a rhesus monkey head would produce a behavioral change and if this change was dose related. Two rhesus monkeys were trained on a repeated acquisition task for 39 days at which time an irradiation series was initiated. Irradiation was performed in the experimental chamber via a helmet facility immediately prior to the behavioral test session. Integral dose rates of 10, 15, 20 and 25 W were administered randomly at least twice during the 100-day irradiation series. Duration of irradiation was two minutes or until convulsion began. Two sets of reinforcements schedules were tested under similar irradiation conditions. Under FR, reinforcement occurred after every 4th correct response, while under VR it occurred on the average for every 4th correct response. Results showed that under VR conditions, irradiations at 25 W consistently produced deficits in performance. Irradiation at lower power levels produced smaller deficits in performance in the early part of the session. The effects on FR performance were less dramatic. Performance following irradiation fell within the range of normal performance except during the first 10 trials after 25 W. (Duration of contract not known.)

SUPPORTING AGENCY:DHEW, FDA, BRH, NSS

0062 MICROWAVE RADIATION EFFECTS ON SIMPLE
DISCRIMINATION AND GENERALIZED TASKS.
Galloway, W. D. (Bur. Radiol. Hlth., Rockville,
Maryland 20852).

The objective of this project was to investigate the effects of microwave radiation using a 2450 MHz continuous wave diathermy type applicator on the performance of a simple discrimination and generalization task. Four rhesus monkeys were trained on a VI-DRO schedule until baseline responding was reached. This schedule was maintained over a nine month period during which approximately 2-minute doses of irradiation at

5, 10, 15 and 20 watts were delivered twice each prior to a normal session. Following this series of random irradiation, two generalization tests were given, one with 10 watts and the other without radiation. T-tests for differences between control day vs experimental (radiation) day showed no significant results for VI-DRO schedule. Generalization data showed a significant radiation effect, but this interference is unreliable as there is evidence of an important dependence on the response to radiation in the animal being tested. (Duration of contract not known.)

SUPPORTING AGENCY:DHEW, FDA, BRH, NSS

0063 BEHAVIORAL SUPPRESSION BY 383 MHz
RADIATION. Cunitz, R. J.; Galloway,
W. D.; Berman, C. M. (Bur. Radiol. Hlth.,
Rockville, Maryland 20852).

The objective of this study was to determine whether microwave radiation via 383 MHz resonant cavity, affected performance on a four-choice, forced choice serial reaction task. Two rhesus monkeys were irradiated for 1 hr immediately before and during performance on the task which then lasted a maximum of 2 hr. Integral dose rates of 0.001 through 17.5 W were delivered to the head. No effects were observed below a critical dose level (≈ 23 W/kg) derived from integral dose rate and body mass. Above this level, behavioral suppression occurred, i.e., correct response rate was profoundly altered. The effect was completely reversible and repeatable in one of the subjects; the other subject did not recover completely and was sacrificed for histological examination which revealed no gross or microscopic damage. The nature of the effect suggests a neurochemical rather than a direct electrical or mechanical basis for the results. (Duration of contract not known.)

SUPPORTING AGENCY:DHEW, FDA, BRH, NSS

0064 PERSONNEL TECHNOLOGY: THE EFFECTS OF
IONIZED AIR AND RADIO ENERGY UPON THE PER-
FORMANCE OF NAVAL PERSONNEL. (E.) Frey, A. H.
(Randomline Inc., Willow Grove, Pennsylvania 19090).

This work is concerned with the effects of exposure to radio frequency energy and ionized air on the neutral activity and behavior of naval personnel. Work planned for the coming year includes (1) further work with air ions emphasizing the mechanisms of effect on behavior and brain chemistry; in particular, the effect of positively charged ions and (2) extension of work in motivational effects of RF energy possibly using fluorescence techniques to study neural changes and relate them to behavioral changes. (7/73-6/74)

SUPPORTING AGENCY:US Department of Defense, Navy

0065 BIOPSYCHOLOGICAL STUDY OF MICROWAVE

CURRENT RESEARCH

Biological Effects Electromagnetic Radiation I(1), June 1974 and I(2), September 1974

IRRADIATION. (E.) Justesen, D. R. (Univ. Kansas, Sch. Med., Kansas City 66101).

The following description records the observations of this project to date. Murine subjects were irradiated in a modulated 2450 MHz microwave field. It was observed that dosing rates of energy just above the threshold of sensory detection (2 mW/g) or 5 times greater (10 mW/g) were associated with rises in colonic temperature which paralleled temperatures engendered by near threshold (and 2 times greater) electrical shocks to the feet. Radiation and footshock, taken in combination, were additive with respect to the amplitude of the evoked thermal response. Anesthetized animals exhibited little thermal reaction to either class of stimulation. The evoked thermal response thus shares with the electroencephalogram (EEG) the capability of indexing emotional arousal and central nervous system reactivity to "novel" stimuli. (6/74-5/75)

SUPPORTING AGENCY:USD HEW, PHS, FDA, BRH

0066 BIOLOGICAL EFFECTS OF AIR FORCE TRANSMITTER NEAR FIELDS. (E.) Stavinoha, W. B.; Medina, M. A. (Univ. Texas. Sch. Med., San Antonio, 78229).

The independent and synergistic effects of high frequency band (3-30 MHz) magnetic and electric field vectors will be studied and assessed in a variety of biological systems using the United States Air Force "near-field" radiation simulator. A large variety of mammalian systems are to be exposed in the simulator and studied to detect any possible alterations in (1) growth and reproduction, (2) central nervous system (neurotransmitter turnover, brain nucleotide levels, brain cyclic AMP assay), (3) endocrine status (corticosteroid assays depending on experimental animal, water balance, VMA, norepinephrine and epinephrine analysis), (4) hematology in Primates and (5) liver and renal functions. In selected animals specific examination of the heart will be undertaken. Such information is required to establish personnel exposure criteria in close proximity to Air Force High Power Radiofrequency radiation emitters operating in the frequency range of approx. 3-500 MHz. (7/73-6/74)

SUPPORTING AGENCY:US Department of Defense, Air Force

0067 PERSONNEL TECHNOLOGY: OCEAN ENGINEERING AND BIOMEDICAL RESEARCH. (E.) Wheeler, E. J. (Wheeler Industries, Inc., Washington, D.C. 20036).

The objective of this work is to provide technical assistance with Navy biomedical programs related to electromagnetic radiation and deep submergence. A "Deep Submergence Biomedical Workshop" will be held in addition to meetings on the biomedical effects of electromagnetic radiation. New and existing Navy programs will be reviewed utilizing information gained from the workshops and meetings and recommendations for program changes will be made. (7/73-6/74)

SUPPORTING AGENCY:US Department of Defense, Navy

0068 QUANTITATIVE EFFECTS OF EM ENERGY ON HUMAN TISSUE. (E.) Guy, A. W.; Lehman, J. F.; Lin, J. C.; Taylor, E. M.; Emery, S. F. (Univ. Washington, Sch. Med., Seattle 98105).

Interdisciplinary theoretical and experimental investigations are proposed to further advance the current knowledge of electromagnetic (EM) interaction with the human body. Of particular interest are (1) the quantitative effects of EM energy on the neural, circulatory and respiratory physiology, (2) the mechanisms of interaction, (3) the absorption of EM energy by humans and animals as a function of body size and source frequency, (4) the thermal significance and/or consequences of total or partial body exposure to EM radiation, and (5) the establishment of safety guidelines for patient and health care personnel during therapeutic usage of EM devices. The emphasis of these studies is on the accurate determination of dose-effect observations and quantitative extrapolations of animal experimentation to human exposure. (6/74-5/75)

SUPPORTING AGENCY:US DHEW, PHS, FDA, BRH

0069 CARDIAC OUTPUT MEASUREMENT BY MEANS OF RF ATTENUATION MEASUREMENT. (E.) Frazer, J. W. (US Air Force Sch. Aerospace Med., San Antonio, Texas 78235).

The objective of this effort is to develop a microwave attenuation measurement capable of detecting changes in cardiac output in adverse Air Force environments without disturbing the subject. Cardiac heart output determinations are necessary to acquire physiological data on which to base safe exposure criteria for Air Force operational environments. Present means of cardiac output measurement in high acceleration or radiation environments depend on vascular intervention with subsequent laboratory analysis of blood or respiratory gases. Alternatively, the subjects are exposed to appreciable doses of ionizing radiation for chest fluoroscopy with subsequent film development and analysis. Scanned frequency RF measurements of the chest will be followed by interferometry at selected wavelengths. (7/73-6/74)

SUPPORTING AGENCY:US Department of Defense, Air Force

0070 EFFECTS OF SEROTONIN-INHIBITING DRUGS ON THE PERFORMANCE OF ANIMALS UNDERGOING RADIO FREQUENCY (RF) IRRADIATION. Galloway, W. D. (Bur. Radio. Hlth., Rockville, Maryland 20852).

Previous research has suggested that decreases in behavioral output resulting from 383 MHz radio frequency radiation may be due to alterations in brain levels of certain neurohumors. This hypothesis is investigated by examining the effects of parachlorophenylalanine and fenfluramine at various dosages on the performance of RF irradiated monkeys. The behavioral baseline

is a four-choice, forced choice serial reaction task. (Duration of contract not known.)

SUPPORTING AGENCY:DHEW, FDA, BRH, XSB, NSS

SOURCES:Author, Principal Investigator, or Other

Ashwood-Smith, M. J., Acting Chairman, Department of Biology, University of Victoria, Faculty of Arts and Sciences, P.O. Box 1700, Victoria, B.C., Canada V8W 2Y2 (604)477-6911, Local 737.

"Preservation Studies at Low Temperature of Cells and Organs with Special Reference to the Effects of Pluronic and Microwave Thawing" (Research Grant). The usefulness of microwave thawing in studies on the freeze preservation of cells, tissue and organs will be investigated.

Cohen, B. H., Professor, Department of Epidemiology, John Hopkins University, School of Hygiene and Public Health, 615 North Wolfe Street, Baltimore, Maryland 21205 (301)955-3977.

Current research activities in biological effects of nonionizing electromagnetic radiation (microwave and radio frequency radiation) include (1) completion of analysis of data on microwave exposure of fathers of a group of children with Down's syndrome and matched controls and (2) ancillary study of screening of blood samples from fathers with a history of microwave exposure and matched unexposed controls to determine whether there are any discernable differences in chromosome abnormalities.

Fanslow, G. E., Associate Professor, Electrical Engineering and Engineering Research Institute, Iowa State University, 122 Coover Hall, Ames, Iowa 50010 (515)294-6576.

Proposals for funding are being prepared to cover work in the soil, the effects on eggs treated to sub-ovicidal pulses and possible side effects on other organisms.

Foster, K. R., Biophysicist, Naval Medical Research Institute, Biophysics Division, National Naval Medical Center, Bethesda, Maryland 20014 (301) 295-0372.

Present research activities are related to the "microwave hearing" effect. Results indicate that this effect arises from the perception, by bone conduction, of thermally generated sound transients in the subject's head.

Houk, W. M., LCDR MC USN, Naval Aerospace Medical Research Laboratory, Biomedical Sciences Division, Pensacola, Florida 32512 (904)452-2556, Ext. 2557.

Detailed investigations are being made into metabolic, thermoregulatory and neuroendocrine responses of small mammals (rodents) to microwave radiation exposure. All responses are related to time and intensity of exposure. Particular emphasis is being placed on field pattern

description in the presence of the experimental animal, and in relating energy incident to energy absorbed. After the end-points have been derived, attempts will be made to elicit mechanisms of biological response by simultaneously raising or lowering environmental temperature while irradiating the animals and studying the responses produced.

Mickey, G. H., Senior Scientist and Dean of Graduate School, The New England Institute, Cytogenetics, 90 Grove Street, P.O. Box 308, Ridgefield, Conn. 06877 (203)438-6591.

"Non-Thermal Hazards of Exposure to Radiofrequency and Microwave Fields" (Research Contract). Objectives of this project are (1) to determine the tolerance limits of exposure to radiofrequency and microwave fields; the amount of exposure mammals (including man) may withstand with no appreciable injury, (2) to study the physical parameters involved in determining these limits-such factors as frequency, average power, peak power, pulse rates, integrated exposure time, recovery time between exposures, and biological characteristics of the test species including their relation to man.

Nelson, S. O., Research Leader, U.S. Department of Agriculture, Agricultural Research Service, Room 5, Agricultural Engineering, University of Nebraska, Lincoln, Nebraska 68503 (402)472-2945; (402)475-3616, FTS

The use of radiofrequency and microwave energy for the control of stored-grain insect species and treatment of seeds to improve germination is being studied. Measurements are being made of the dielectric properties of insects and grain over a wide range of frequencies (audiofrequencies through X band and K band). While observed effects on insects appear to be mainly of thermal origin, possible nonthermal biological effects are of interest because confirmed athermal effects detrimental to insects would be of value in improving the effectiveness of insect-control treatments.

Varma, M. M., Professor and Director, Bio-Environmental Engineering and Sciences, Howard Univ., School of Engineering, 2300 Sixth Street, N.W., Washington D.C. 20059 (202)636-6574.

Toxicology studies were performed by exposing the testes of anesthetized 56 day old male mice, at 1.7 and 3.00 GHz, the power densities were 10 mW/cm² and 50 mW/cm², for each frequency. The exposure time varied from 5 min to 180 min. Mating studies based upon toxicology studies are being conducted at LD₅₀, LD₁₀. Each male is mated with 3 unexposed virgin females for one week; the females are replaced each week for 6 consecutive weeks. All females are autopsied on Day 13, and scored for pregnancy and the total number of implants (comprised of living implants and late fetal deaths); the latter appearing as small black decidumata. Results are compared with concurrent control groups.

CURRENT RESEARCH

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Osaka, A., Chief of Second Internal Medicine, Sapporo Hosp., North 1st, West 9th, Hokkaido, Japan, 060, 261-2281.

Current research activities involve the effect of microwave radiation on malignant tumors. Malignant tumors induced on rats by injection of methyl-cholanthren were exposed to microwave radiation. As an example, a mass about 4 cm in diameter was cured completely by one exposure to radiation, the coagulated necrotic tumor tissue falling off afterwards.

Oscar, K. T., Senior Physicist, Army Mobility Equipment Research and Development Center, Military Technology Department, Fort Belvoir, Virginia 22060 (703)664-5606, 664-5740.

Current research seeks to identify specific physiological or behavioral responses caused by microwaves and to get dose response data on them as a function of frequency, dose (power density, time) and animal specie. Approximately 90% of this effort is contracted out. A small in-house effort is being carried out on the phenomena of RF sound.

Phillips, R. D., Research Associate, Battelle, Pacific Northwest Laboratory, Biology Department, P.O. Box 999, Richland, Washington 99352 (509)946-2269.

Present studies are concerned with the behavioral and physiological effects of pulsed microwaves.

Rabinowitz, J., Associate Research Scientist, New York University Medical Center, Institute of Environmental Medicine, 550 First Ave., New York, New York 10016 (212)679-3200, Ext. 5247.

The mechanisms for the basic interactions between microwave radiation and biological molecules, along with possible functional implications, have been considered. Specific systems are being investigated where biological changes induced by microwave radiation suggest possible functional changes on the molecular level. The systems are: (1) uptake of ascorbic acid by the rabbit lens; (2) uptake of known actively transported compounds in rabbit lens; (3) activity of acetylcholinesterase; (4) cation transport in red blood cells.

Milroy, W. C., Head, Biomedical Research Team, Naval Weapons Laboratory, Weapons Safety Division, USNWL, Biomedical Research Team, Code ESR, Dahlgren, Virginia 22448, (703)663-7139.

The Special Effects Biomedical Research Department is concerned with the health and safety of personnel exposed to nonionizing electromagnetic radiation, particularly high peak power pulse systems. Our research includes a medical surveillance program and animal experimentation. Current research is being done on reproduction and longevity, hepatic enzymes, hematology, and behavioral factors.

Programs which are being initiated include cell cycle timing, biorhythms, and neurochemical and neuroelectrical activity.

Mitchell, J. C., Chief, Radiation Physics Branch, USAF School of Aerospace Medicine, Radiobiology Division, Brooks AFB, San Antonio, Texas 78235 (512)536-3582.

The Radiobiology Division (RA) of the USAF School of Aerospace Medicine is the AF office of primary responsibility for all microwave and radiofrequency radiation bioeffects research. The school has unique HF band (3-30 MHz) exposure and measuring capabilities including a large (nominal 2x3x10 meter) coaxial waveguide for uniform "far-field" exposures and a "near-field" radiation simulator for studying E- and H-field bioeffects. A complete series of E- and H-field measuring probes and a differential power absorption measuring system, all designed and calibrated by the National Bureau of Standards, are routinely used in the School's bioeffects studies. The School's RF facilities also includes a 40-400 MHz exposure strip line, an anechoic chamber and both MCL and Cober generators to cover the frequency range from 30 MHz to 14 GHz. The in-house RF research includes studies of rodent growth rate, water metabolism in rodents, gross oxygen uptake, subcellular distribution of divalent metals, lymphocyte division, neurotransmitter turnover in the brain, and thermal distribution. The School's RF contract program includes studies of the effects of VLF band radiation, electric and magnetic effects of HF band fields on isolated macromolecules, biological effects of high amplitude pulsed fields, thermal distribution of absorbed power in man models, and frequency dependence of power absorption.

Mittler, S., Professor of Biological Sciences, Northern Illinois University, Department of Biological Sciences, DeKalb, Illinois 60115 (815)753-1884.

Experiments are being conducted on the mutagenic effects, if any, of 146 MHz and 29 MHz on *Drosophila*. Future research plans involve studying the effects of 2450 MHz on homing behavior in pigeons.

Wachtel, H., Associate Professor, Duke University, Departments of Biomedical Engineering and Physiology, Durham, North Carolina 27706 (919) 684-6185.

The immediate effects of microwaves on individual nerve cells are being investigated. In some cases changes are seen in firing rhythms resulting from absorbed powers less than 10 mW/cc which seem to be thermally nonreproducible. Some form of current detection mechanisms is implied by the results. Future interest lies in looking at long term exposure effects (> 1 month) on both neuronal activity and organism behavior.

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